JUL 31 1944

JULY, 1944 Medical Library Vol. 120, No. 1

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ANNALS of SURGERY

A Monthly Review of Surgical Science and Practice

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ANNALS OF SURGERY

VOL. 120 JULY, 1944 No. 1

THE TREATMENT OF AIR FORCE COMBAT CASUALTIES

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NEW YORK, N. Y.

IN A PERIOD of approximately seven months 198 officers and men of the United States Army Air Force were admitted as battle casualties to an Evacuation Hospital which was functioning as a fixed Station Hospital. Twenty-two of these had received definitive treatment in other hospitals. Treatment of the remaining 176 patients had been limited to first aid measures.

The great majority of casualties were caused by enemy gun fire. Other causes in order of frequency were freezing of fingers, toes, and other parts of the body, violent contact with parts of the plane or the earth's surface, burns, and anoxia.

The total number of casualties due to missiles was 141, and the enemy weapon responsible for the great majority was the 20-Mm. aircraft cannon shell (Table I). Upon explosion these small shells throw out many small

TABLE I

NUMBER OF CASUALTIES PRODUCED BY THE VARIOUS TYPES OF MISSILES

Aircraft cannon shells, 20-Mm.	99
Machine gun bullets	17
Anti-aircraft cannon shells	12
Secondary missiles from aeroplane	7
Unidentified missiles	5
Rocket shell	1
Total	141

fragments in all directions. If the explosion occurs at some distance the resulting wounds may be slight, but if the shell explodes nearby it is very destructive. In either case the numerous small fragments are a great danger to the eyes. Other missiles causing injury were, in order of frequency, machine gun bullets, anti-aircraft shell fragments, secondary missiles consisting of plane parts, unidentified missiles, and rocket shell fragments. At about the time rocket shells came into use there was a noticeable increase in the number of the wounded who did not know the source of the missile that had struck him. It is probable that some of these unidentified missiles were from rocket shells.

Twenty-two casualties were due to the freezing of various parts of the body at high altitude. These were transferred as soon as practicable to a

General Hospital where special studies of frostbite were being conducted. Two additional patients had severe wounds as well as frostbite.

Eight casualties were caused by violent contact with plane parts or the earth's surface, and in most instances were the result of forced landings or parachute jumps.

Burns, fortunately, were only three in number, and not severe.

There were two cases of anoxia, one of which was profound. After more than 24 hours of unconsciousness this patient began to show signs of orientation, and within a few days his recovery appeared to be complete.

The distribution of wounds with respect to the parts of the body involved is shown in Table II. The extremities were injured more frequently than other parts of the body. In this the historical pattern of war wounds is followed.

TABLE II

THE ANATOMIC DISTRIBUTION OF WOUNDS CAUSED BY MISSILES*

I	*Body as a Whole:*	
	Scalp	18
	Face	53
	Eye	18
	Ear	2
	Neck	16
	Shoulder region	23
	Arm	37
	Forearm	20
	Hand	16
	Chest wall	32
	Abdominal wall	6
	Lumbar region	4
	Gluteal region	13
	Thigh	39
	Leg	25
	Foot	11
II	*Fractures of Bones:*	
	Skull	4
	Maxilla	1
	Mandible	1
	Clavicle	1
	Humerus	4
	Ulna	3
	Radius	1
	Phalanx, manual	4
	Metacarpal	8
	Rib	3
	Ilium	1
	Pubis	1
	Femur	3
	Patella	1
	Tibia	5
	Tarsal	2
	Metatarsal	5
	Phalanx, pedal	2
III	*Injuries to Tendons:*	
	Flexor tendons, carpal	1
	Flexor tendon, digital	2
IV	*Injuries to Joints:*	
	Elbow	2
	Knee	2
	Ankle	1
V	*Nervous System:*	
	Brain	5
	Facial nerve	2
	Cervical plexus	1
	Phrenic nerve	1
	Brachial plexus	3
	Ulnar nerve	4
	Medial antibrachial cutan.	1
	Median nerve	4
	Radial nerve	4
	Sacral plexus	1
	Peroneal nerve	2
VI	*Respiratory System:*	
	Pleura	1
	Lung and pleura	7
VII	*Digestive System:*	
	Liver	3
	Small intestine	1
	Colon	2
VIII	*Genito-urinary System:*	
	Prepuce	1
	Scrotum	1
	Bladder	1
IX	*Circulatory System:*	
	Temporal artery	1
	Brachial artery	1
	Radial artery	2

* The figures indicate the number of times an anatomic part was injured and not the actual number of wounds.

After the extremities, the face came next in the order of wound frequency. In a total of 141 airmen wounded by gun fire, 53 (37.5 per cent) received wounds of the face. Among the patients with face wounds there were 18 eye injuries, approximately 12 per cent of the total number of 141 wounded. This is appreciably higher than the general incidence of eye injuries in World War I, which Matthews,[1] quoting Meisner, gives as 5 to 8 per cent.

The chest wall and scalp received numerous missiles but penetrations into the lungs and brain were relatively few. Wounds of the shoulder and gluteal regions were frequent, but as a rule not serious.

Compound fractures were fairly numerous. The fragments of aerial cannon shells were capable of fracturing the smaller bones, but had insufficient force to fracture a large bone unless the shell exploded nearby. The majority of fractures of the large bones were caused by heavier missiles.

The brain was damaged in five instances, but injuries to the nervous system concerned chiefly the peripheral nerves. A number of the nerve injuries were of a temporary nature, and probably due to contusion by secondary missiles arising from particles of tissue set in motion by the wounding agent. In some instances, however, long segments of important nerves were destroyed.

Wounds of the tendons, joints, digestive system, genito-urinary system, and the circulatory system were not numerous, but often were interesting and perplexing.

The treatment of wounds received in aerial combat was something in which none of the surgical staff was experienced, and there were no directives on this particular group of battle casualties. Many articles had been written on the treatment of wounds of the present war, but nearly all available information pertained to land or sea warfare. The opinion was virtually unanimous that the surgical measures should consist of thorough débridement, the application of a sulfonamide to all surfaces and recesses of the wound, packing with plain or medicated gauze, and immobilization of the injured part. The primary closure of wounds was mentioned but almost universally condemned.[2-9]

In the treatment of our earlier casualties we conformed to the general practice and treated all wounds by the open method. As a rule they healed well, and few became infected. The healing of open wounds by granulation, however, is a slow process, and it was obvious that much time might be saved by primary suture provided it was successful. In wounds as clean as these had proven to be, healing by primary union seemed a reasonable expectation.

Primary closures were first carried out in the more favorable cases and gradually extended to include the greater part of the wounds treated. Débridement and the application of sulfanilamide were done in the usual manner.

The results, which are shown in Table III, appear to have justified

this method of treatment. Healing by primary union was obtained in 244 (95 per cent) of the total of 257 wounds that were closed. Thirteen wounds (5 per cent) did not heal by primary union. Nine of these (3.5 per cent) were reopened, or opened spontaneously, because of frank infection; three wound were reopened by the surgeon in the belief that they were infected, but cultures were negative; the edges of one uninfected wound separated because it had been closed under too much tension.

TABLE III

METHODS OF WOUND TREATMENT

Wounds débrided and closed	257
Subsequently infected	9
Subsequently reopened but not infected	4
Wounds closed by secondary suture	4
Subsequently infected	0
Subsequently reopened	0
Wounds closed but not débrided	3
Subsequently infected	3
Wounds débrided and left open	68
Subsequently infected	16

An investigation of subsequent results was made in all of the 244 wounds that had healed by primary union and it was found that none had broken down. The investigation was conducted three to five months after the original closure of the wounds and was greatly facilitated by the cooperation of the Surgeons of the Air Force and the General Hospital to which some of the patients were evacuated.

Secondary closure was done in four wounds. Three of these were in patients transferred from other hospitals with open wounds, the fourth was one of our own patients. All healed by primary union. Secondary closure should be particularly useful as a planned procedure in certain fresh wounds which cannot be thoroughly débrided and in old wounds which have become relatively clean.

Wounds débrided and left open were 68 in number, and 16 (23.5 per cent) of these subsequently developed infection. It should be explained that the open method of treatment was reserved for wounds too large to permit closure, wounds which could not be débrided satisfactorily, and wounds which because of reduced vascularity were considered to have more than the usual susceptibility to infection. The high incidence of infection in this group, therefore, cannot be attributed to the open method of treatment.

Three wounds were sutured without débridement. Two of these were wounds of the face in which preservation of tissue was a primary consideration, the third was a wound of the thigh which had been sutured at the Unit Dispensary. The importance of débridement is emphasized by the fact that all of the three wounds sutured without débridement became infected.

Infection led to serious consequences in only four of the entire series of cases. One patient died of peritonitis four days after the suture of multiple

perforations of the ileum and cecum. Two patients had midthigh amputation for gas gangrene; in both instances the infection developed in compound fractures of the bones of the leg; in one case the wound had been partially closed and lightly packed with vaselined gauze, in the other it had been left entirely open; one patient survived, the other succumbed 11 days after injury. The fourth serious infection occurred in a patient who had a large penetrating wound of the bladder. There was some urinary leakage after suture and an obstinate retroperitoneal infection developed. All other infections were of minor importance.

According to Lenormant[10] the primary suture of certain war wounds was started in 1915. He states that Lemaitre was able to carry out primary suture in 2,664 of 4,000 wounded, and the result was successful in 2,549 (95.6 per cent), but the cases for this procedure were selected with the greatest care. Primary suture was practiced to some extent by surgeons of the United States Army in World War I,[11] and when done under favorable circumstances good results were obtained.[12] Heuer,[13] working in an Evacuation Hospital near the front, was able to make primary closures on approximately 600 wounds, with success in 95 per cent. The 5 per cent of failures were wounds which subsequently showed evidence of infection, and were opened by removal of sutures.

In the present war the primary closure of wounds, as already stated, has been looked upon with disfavor in all the principal theaters of action. No doubt there are good reasons for this attitude, particularly with respect to ground troops. A number of considerations, however, serve to differentiate wounds sustained in the air from those received on the ground:

1. Bomber crews live under conditions which approach those of civilian life. They are comfortably housed, well fed, and have facilities to maintain cleanliness of body and clothing. The time between leaving the base and entering combat is a matter of a few hours at most, and the men go into action in good physical condition. None of these advantages obtain for the ground forces.

2. The missiles that inflict injury upon airmen are not grossly contaminated by earth, or other material from the earth's surface, and carry no foreign substances into the wounds except bits of clothing and occasionally secondary missiles derived from the plane itself.

3. Efficient first aid treatment, which includes the use of sulfanilamide, is administered in the plane immediately after injury, and as soon as the wounded arrive at the air field the medical personnel carry out whatever measures are necessary to assure their arrival at the hospital in the best possible condition.

4. Wounded airmen usually receive definitive surgical treatment within four to six hours of the time of injury. Ground troops often must wait many hours or even days.

With these considerations before us, it is obvious that important differences exist between air and ground force casualties. In treating the wounds

FIG. 1

FIG. 2

FIG. 1.—*Case A:* Appearance of leg upon admission to the hospital. The number and extent of wounds made satisfactory débridement impossible.

FIG. 2.—*Case A:* Roentgenogram of leg showing comminuted fractures of the tibia. Numerous shell fragments are scattered throughout the soft parts.

of aerial warfare these differences should be recognized and turned to advantage.

Before leaving the subject of treatment something should be said about shock as observed in wounded airmen. In brief, it may be stated that profound shock was not encountered except in those who had bled profusely. Other factors productive of shock, such as dehydration, physical exhaustion, and prolonged anoxia of the tissues, did not appear to have been severe enough to make them important as causative agents. Treatment with plasma yielded best results when given in large amounts, but the improvement could hardly be called spectacular. As a rule, the blood pressure did not rise to a satisfactory level and the general response was only a partial recovery. It is questionable whether plasma administration gave much better results than might have been obtained with physiologic saline and glucose. Definite recovery from shock usually did not become evident until the patient had received a transfusion of whole blood, and the degree of recovery was proportional, in a general way, to the amount of blood given. The results conformed to what might be expected in shock of almost purely hemorrhagic origin.

TABLE IV

SUMMARY OF RESULTS

	Discharged to Duty	Transferred to other Hospitals	Died	Total
Casualties produced by:				
Missiles	104	35	2	141
Violent contact with plane parts or earth's surface	7	1	0	8
Frost	3	19	0	22
Burns	3	0	0	3
Anoxia	1	1	0	2
Total	118	56	2	176

A general summary of results obtained in the total series of 176 air force battle casualties is given in Table IV. It will be observed that 104, (73.7 per cent), of the 141 airmen wounded by missiles were returned to duty directly from the evacuation hospital; 35 (24.8 per cent), were transferred to other hospitals; and two (1.4 per cent), who have already been described, died of their wounds.

Some of the problems of treatment may be illustrated by three cases which for convenience are designated as A, B, and C:

ILLUSTRATIVE CASE REPORTS

Case A.—This patient sustained multiple wounds of the soft tissues of the left leg and compound, comminuted fractures of the tibia (Figs. 1 and 2). The fibula was intact. A tourniquet had been applied above the knee and was still in place upon admission to the hospital. In spite of this the patient had bled profusely and was in shock. The tourniquet was removed and pulsations were felt in the dorsalis pedis and posterior tibial arteries. The damage to the leg was so extensive that a thorough débridement of all

FIG. 3 FIG. 4

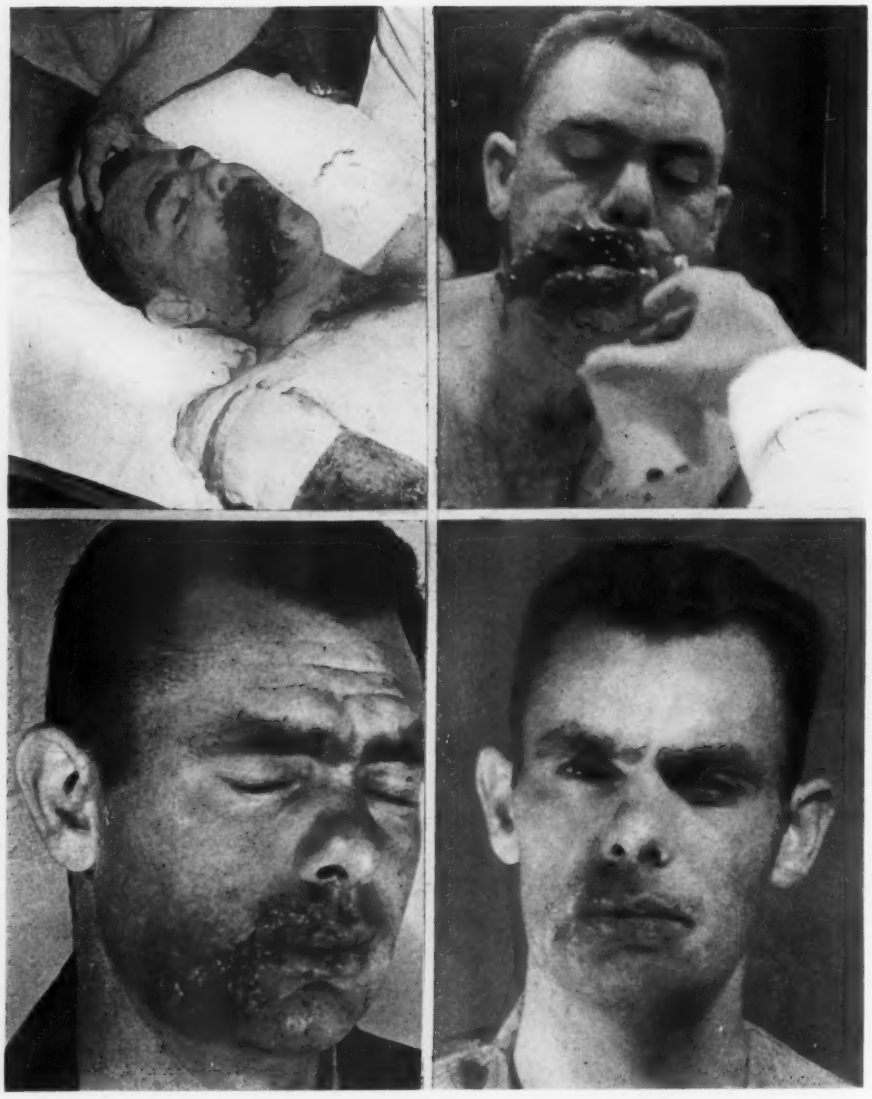

FIG. 5 FIG. 6

FIG. 3.—*Case B:* Extensive laceration of cheek involving the lips and angle of the mouth. There was also a compound fracture of the mandible.

FIG. 4.—*Case B:* Injury to the face as seen from the front.

FIG. 5.—*Case B:* Appearance of face approximately two weeks after incomplete débridement and suture. There was slight infection and partial separation of the wound edges.

FIG. 6.—*Case B:* Appearance approximately six weeks after injury. The result illustrates the advantages of conservative débridement and immediate repair of facial injuries.

wounds was out of the question. The circulation, however, appeared adequate and the innervation was not seriously disturbed.

A fairly satisfactory débridement was done on the larger wounds, microcrystalline sulfathiazole was instilled, and the leg and thigh were immobilized in plaster. None of the wounds were sutured. Sulfadiazine was given by mouth for eight days after operation, and progress seemed quite satisfactory. On the ninth day there was complaint of some pain in the leg which was relieved by loosening the encasement. On the tenth day there was some fever; the leg was moderately swollen but there was no crepitus. On the eleventh day there was increased swelling, profuse, serous discharge, and slight localized crepitus. After a large transfusion, a midthigh amputation was performed, but the patient succumbed the same day. A different result might have been obtained if the gas gangrene had been recognized earlier.

FIG. 7 FIG. 9

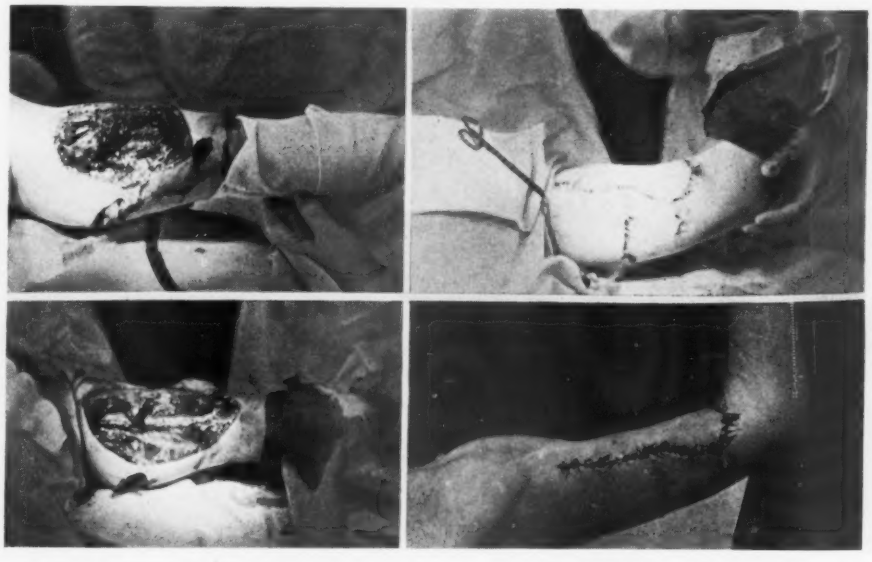

FIG. 8 FIG. 10

FIG. 7.—*Case C:* Appearance of left arm with multiple wounds prepared for débridement. The neurovascular trunk is visible in the depth of the large wound.

FIG. 8.—*Case C:* The wounds after débridement. A skin incision was made at the distal angle of the large wound to include the two smaller wounds seen in Figure 7. Skin excision was limited to a few millimeters of the wound edges.

FIG. 9.—*Case C:* Wounds immediately after primary suture. In spite of the large size of the wounds closure was effected without tension.

FIG. 10.—*Case C:* Appearance of wound immediately before removal of sutures. Healing was by primary union.

Case B.—This patient was struck near the angle of the mouth by an enemy missile thought to be a machine gun bullet. Considerable damage was done to the soft parts of the face and there was a compound fracture of the mandible (Figs. 3 and 4). In spite of these injuries and a deep wound of the right deltoid muscle, this pilot brought his fortress home and made a good landing.

A complete débridement of the facial wound would have left a large defect and extensive plastic procedures requiring months of hospitalization would have been necessary. Excision of tissue, therefore, was confined to the dry, blackened shreds which were in effect foreign bodies. The wound was then sutured with care as to anatomic relationships.

Healing was complicated by slight infection and partial separation of the wound edges (Fig. 5), but the final result was relatively good (Fig. 6).

Case C.—In addition to other serious injuries this patient received a severe flesh wound of the left arm which involved destruction of a good part of the biceps muscle and the soft tissues of the medial surface of the arm (Fig. 7). A segment of the ulnar nerve also had been shot away. There were other smaller wounds of the anterior and medial surfaces of the arm and a shell fragment had punctured the brachial artery near the antecubital fossa. After débridement had been completed (Fig. 8), it was possible to close the wounds without tension (Fig. 9). Healing was by primary union (Fig. 10), and there was undoubtedly much less scar formation than would have resulted from open treatment. Prompt healing made possible an early attempt at nerve repair and avoided the impediment of dense scar tissue.

CONCLUSIONS

1. The primary closure of wounds has obvious advantages when conditions are right for its use.

2. The wounds of aerial combat are received under peculiarly favorable conditions and many of them can be débrided and closed with good prospect of primary healing. In this series, 95 per cent of 257 wounds closed by primary suture healed without infection or separation of the wound edges.

3. Primary suture should not be attempted in wounds that are too large to permit closure without tension; in wounds which, for some reason, cannot be débrided satisfactorily; nor in wounds where adequate vascularity is in doubt.

4. Secondary wound closure is useful as a planned procedure in doubtful fresh wounds and in old wounds that have become relatively clean.

5. The open treatment of wounds has almost universal indorsement in ground force casualties. The indications for open wound treatment in air combat casualties are much more restricted, but it is the preferred method in certain types of injuries. Open treatment, however, does not insure against gas gangrene and other serious infections.

6. The different methods of treating wounds should be considered as complementary and not opposed to each other.

7. The decision as to the closed or open treatment of wounds sustained in aerial combat should be governed by a consideration of the circumstances in the case and not wholly restricted by rule.

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WHOLE UPPER EXTREMITY TRANSPLANT FOR HUMAN BEINGS: GENERAL PLANS OF PROCEDURE AND OPERATIVE TECHNIC*

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TRANSPLANTATION of homologous extremities is not new. The idea has probably occurred to innumerable surgeons, from one time to another, during the existence of surgery.

With the tremendous number of casualties which have occurred, and will occur, in the present war, the feasibility of a whole limb transplant should again be considered. Granted, prostheses have been highly perfected, but with all our modern mechanical skill no mechanism can begin to replace a hand. One machine gun bullet can render a hand useless. Many hands have already been observed with severe, completely disabling burns, shrapnel wounds, crush wounds, *etc.* At the present time there is nothing to offer these men but partial compensation in the form of a veteran's income. Hence, there exists a need for successful whole limb transplantation.

As early as 1897, Halsted succeeded in transplanting the hind leg of a dog from one side to the other, leaving the principal artery intact until the various tissues sectioned had healed. MacCallum, in studying inflammation, completely amputated an extremity and replaced it by anastomosing the blood vessels and bringing together muscles and skin. In 1906, Carrel and Guthrie showed the feasibility of a whole extremity graft by transplanting a recently severed extremity from one dog onto the prepared stump of another. They repeated this work on several occasions, and had such success that they considered the matter closed. The procedure was certainly possible, they concluded, but it was not practicable. There was no source for the grafts in human beings. The number of people who would want, or need, such a transplant were too few.

Accordingly, during the next few years, Doctor Carrel digressed from the idea of whole limb transplants and turned to experimenting with organ transplants, again attempting to reestablish normal blood circulation of the transplant in the recipient. These experiments with kidneys of animals are quite familiar to everyone interested in the subject but have no remarkable connection with extremity transplants. However, it was during these years that blood vessel surgery received additional attention. Indeed, the technics of handling and suturing blood vessels were one of the main contributions to surgery from this work. On the other hand, the work was not conclusive enough to warrant kidney or extremity transplants in human beings, so that surgeons confined their grafts to those in which the blood supply was

* The opinions and views set forth in this article are those of the writer and are not to be considered as reflecting the policies of the Navy Department.

Illustrations for this article were made by William B. McNett from Cadaver Dissections done by author at the Daniel Baugh Institute of Anatomy, Philadelphia, Penna.

completely severed, such as skin, corneal, bone, and fascial grafts. The idea that homologous transplants are unsuccessful has evolved from these grafts. However, these grafts are actually not comparable at all, inasmuch as their original blood supply is destroyed after separation from the host. Complete revascularization has to occur before such grafts live. This naturally cannot apply where the blood supply is preserved.

It is important to note a few of the obstacles met with in performing transplants in which the blood supply is preserved. The first of these is infection. Infection is one of the largest factors in production of thrombosis in anastomosed blood vessels. Murphy felt that almost all of the thrombi which formed at the site of blood vessel anastomoses where the intima was undamaged could be attributed to infection in and around this site. Thromboses have been so common in blood vessel surgery that almost all repair of blood vessels has been discouraged. Some of this discouragement resulted from the sad commentary of Sir George Makins on the results of end-to-end arterial suture during World War I. De Takáts, using no anticoagulants nor agents to combat infection, discouraged the excision of emboli from blood vessels after their establishment for more than ten hours. Even during this first ten hours he had only about 40 per cent success.

Today, however, the picture is more promising. To combat infection we have at least two large, relatively new, groups of antibacterial agents. The first group includes the sulfonamides. This group is more popular at present, is synthetic in origin and has its action, apparently, as a static poison to the bacteria attempting to metabolize the substance. The second group is that including tyrothrycin, gramicidin, and penicillin. This field was opened up by Dubos in 1939, and includes natural products which seem to have inhibitive and lytic action directly on the bacteria. With these two groups, already infection is becoming less and less of a problem. Blood vessel surgery is achieving more success. Even grafts where the blood supply is not preserved are reported to take more frequently where control of infection has been attempted.

Thrombosis, another obstacle to preservation of blood supply in transplants, now has two relatively new and directly combative agents. In 1936, Best, Charles, and Scott obtained a purified barium salt of heparin. This heparin preparation is nontoxic to human beings in therapeutic doses and is effective in preventing thrombosis. Its only disadvantage is that of administration, which has to be done parenterally.

As a result of using heparin, Murray reports remarkable successes. He feels that the ten-hour limit for embolectomies no longer holds, and reports 17 successful embolectomies using heparin postoperatively. He also reports three successful end-to-end arterial anastomoses and three cases using venous grafts to bridge gaps between severed arteries. No aneurysmal complications nor thrombi occurred. On one occasion, in repairing a false aneurysm, a section of the vein which was involved in the aneurysmal clot was used.

The clot had to be scraped from the intima of the venous graft and valve cusps had to be removed. In spite of the extensive damage to the intima of the venous graft it remained patent and the graft was successful. Priestley, and his coworkers, at the Mayo Clinic report that heparin is of definite value in prevention and treatment of postoperative thrombosis and embolism. Jaques, and Perett feel that thrombi on intimal surface of veins from chemical or mechanical injury can be completely prevented by the proper use of heparin.

In 1941, Link and his associates isolated and synthesized the causative hemorrhagic agent in spoiled sweet clover disease of cattle, 3, 3'-methylenebis (4-hydroxycoumarin). This substance has been popularly termed dicoumarol. It is not only more economical, but in contrast to heparin has been found to be effective when taken orally. Like heparin, though, it does not appear to be toxic in therapeutic doses. However, it seems to have a latent period of 48 to 72 hours, during which time it is necessary to use heparin following blood vessel surgery. The action of heparin apparently is direct neutralization of the substance thrombokinase. In contrast, dicoumarin seems to act by preventing the liver from forming prothrombin and has no direct effect on the blood itself. The clinical experience of Lehmann, Meyer, Allen, Bingham, Barker, Waugh, and others, gives good evidence that dicoumarin is a valuable adjunct to heparin in the prevention of thrombosis and embolism.

Another problem met with in performing a whole limb transplant is the method of fixation utilized for holding the bony fragments in position. Since Stader presented the advantages of his reduction and external fixation splint to Shaar, Kreuz, and their associates, at the U. S. Naval Hospital in Philadelphia, in 1941, its use has become widespread. It is a strong and light-in-weight splint which permits complete control of bone fragments in all planes, as well as traction, impaction and fixation. The apparatus does not restrict circulation and allows early active motion which makes it highly advantageous for use in a whole limb transplant.

Still other problems arise. One is the decision at which level to undertake the surgical procedure. The level of choice appears to be at the junction of the middle and lower third of the arm. This site is chosen because the structures here are large enough to work with conveniently. There is a single bony shaft and the structures involved are relatively simple. Another problem concerns the availability of the donor for the recipient at the proper time. In the early development of this procedure a surgical team could be trained, working in a well-equipped, large city, base hospital, employing as a source extremities of civil or military casualties. Permits could be obtained where necessary. Those needing grafts could wait in the hospital and be available when the proper graft was obtained. Then, after the procedure has been perfected, such modifications might be developed so as to make it practicable in field hospitals or hospital ships.

Then, again, in time, a method of preserving the limbs for grafting by means of a mechanical heart-lung perfusion apparatus might be perfected,

though this would not be necessary at first. Preservation by refrigeration offers another field of investigation. Certainly the amputation of extremities using ice packing anesthesia is suggestive. Also is the theory that metabolism temporarily ceases at low temperatures as shown in the freezing treatment of malignancies. Carrel demonstrated that small blood vessel grafts after having been stored in saline at slightly above freezing temperature for several days, not only function, but often live in their new host.

The laity, of course, would have to be educated to the idea involved. They would have to be impressed by the fact that the transplant is a living one, not dead. Prostheses met considerable opposition in the early days, but now artificial limbs are accepted entities.

In summary, then, with the advent of the sulfonamides, heparin, dicoumarin, Stader splint, and many other modern medical and surgical developments, there is every chance that a whole limb transplant in man should be possible and successful. Its success should be preceded by animal experimentation and cadaver surgery. There is certainly a growing demand for this procedure. Many technical problems connected with whole limb transplantation will have to be solved as they are met. However, a tentative plan of procedure is being presented.

OPERATIVE PROCEDURE FOR UPPER EXTREMITY TRANSPLANT

I. Preoperative:
   A. Nursing duties:
      1. Scrub operative site well above and below region daily for two or three days, ending on the day of operation with sterile preparation.
      2. Usual nursing care.
   B. Medical duties include:
      1. Supervision of preoperative medications.
      2. Usual preoperative examination to be sure recipient is in good enough condition for surgery.
   C. Technician's duties include:
      1. Typing of recipient's and donor's blood.
      2. Serologic complement-fixation or flocculation tests on each.
      3. Any other laboratory tests as deemed necessary by medical staff.

II. Operative:
   A. Assistant surgeons:
      1. Prepare sterile field.
      2. Aid in surgical procedure as directed by surgeon.
   B. Nurses or trained corpsmen:
      1. Manage instruments, drapes, solutions, *etc.*
      2. Maintain lighting properly.
   C. Anesthetist gives appropriate anesthesia and handles intravenous solutions, medications, and transfusions.
   D. Surgeon's procedure in preparing donor's graft (Fig. 1).

After applying sterile Cohen tourniquet clamp, if necessary, a skin incision is made with unequal anterior and posterior flaps (Fig. 4). The anterior flap comes to about one inch above the elbow crease, the posterior flap to the olecranon, the same as in recipient. An attempt is made to isolate the brachial cephalic and basilic veins superficially. They should be dissected free and tributaries ligated close to the veins for about 6 cm. These veins should be transected at least 8 cm. above the level of the humeral condyles. Careful handling of the distal ends of the veins is important in order to avoid injuring their intimal surfaces. They should be attached to cannulae which lead to a dependent reservoir. The deep veins are cannulated similarly when they are transected later. After securing superficial veins, the skin and subcutaneous tissues are mobilized above and below all around the arm, thus exposing the biceps and triceps muscles in addition to small parts of of the brachialis anticus, brachioradialis, and flexor and extensor groups of the forearm. During this cleaning process brachial and antibrachial cutaneous nerves should be isolated and transected in the upper part of the wound. A small tie can be placed around these small nerves in order to keep track of them. Later on the portion tied can be sacrificed before anastomosis is attempted. The biceps tendon may now be isolated and transected in Z-fashion just below the musculotendinous junction. To facilitate repair, the Z-cut must always be the same, as, for example, a Z rather than an S, approaching the tendon anteriorly.

With the biceps muscle retracted superiorly all the important nerves and vessels can be readily obtained. The brachial artery and veins should be isolated first. They may be cut across as far proximal as possible. The artery should be cannulated to a heparinized transfusion, through which is bubbling oxygen and in which is contained an antibacterial agent such as penicillin or a sulfonamide. The veins, if large enough may be drained as previously directed for the superficial ones. Blood perfuses the extremity continuously and is recirculated as rapidly as possible.

Close to the vessels is the median nerve, which is next in order. It also, is transected proximally. A suture should be placed through the nerve near the cut end in a frontal plane. The suture is tied and then sewed to the skin distally so as to retract the nerve from the field and yet keep it from becoming rotated about its longitudinal axis (Fig. 1). The damaged portion of the nerve is later sacrificed before anastomosis. The radial nerve can usually be found between the brachialis and the brachioradialis muscles near the humerus. It and the ulnar nerves are handled as was the median. The ulnar nerve is usually anterior to the medial muscle fibers of the triceps.

With this much done the lower half pin-unit for the Stader apparatus should be applied. Ample clearance (about 1 inch) for the skin should be allowed between the plastic bar and the triceps muscle. The pins should be placed through the aponeurosis of the triceps as far distally as possible. Care should be exercised so as not to get in the joint nor the humeral epiphysis. When the pins are properly inserted, a Z-incision may be made

through the triceps down to the bone, nearly freeing the muscle and tendon from the pins. A technic for this Z-incision must be adopted consistent with the technic used in the biceps tendon so as to avoid mistakes and confusion. The shaft of the humerus must finally be exposed for a narrow band proximal to the Stader half pin-unit. To do this the brachialis and brachioradialis muscles may be transected at the proper level and loosened subperiosteally

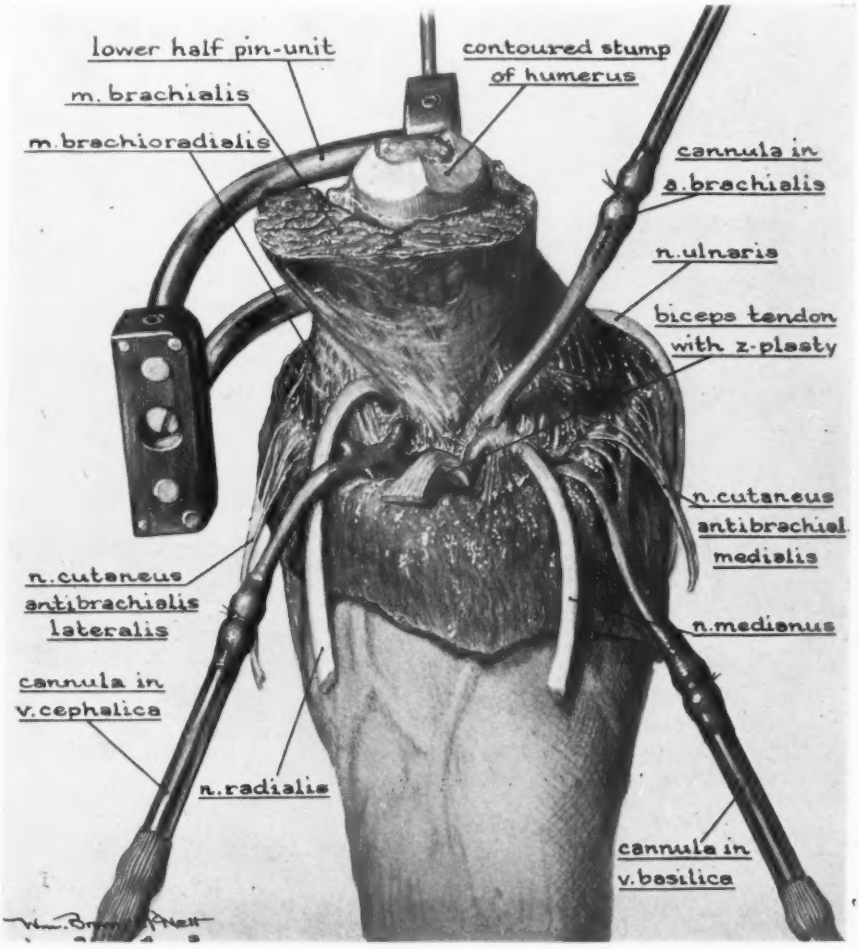

FIG. 1.—Preparation of the donor graft completed.

along with the triceps in order to get adequate exposure. The humerus is finally cut at the junction of middle and lower thirds. Three saw cuts are made from the anterior, medial, and lateral edges of the humerus. The sawteeth point superiorly with the sawblade forming an acute angle with the distal humerus. The end-result is a three-sided cup in the proximal stump and a three-sided pencil tip in the distal fragment (Figs. 1 and 2).

The Stader pins may be used to help steady the arm while sawing. The extremity is finally draped with a sterile towel, and the surgeon takes the graft to the recipient or leaves it attached to perfusion solutions and oxygen tank for preservation. Ice packs may be applied also.

If necessary at this time, proximal stump of donor should be closed as after an amputation.

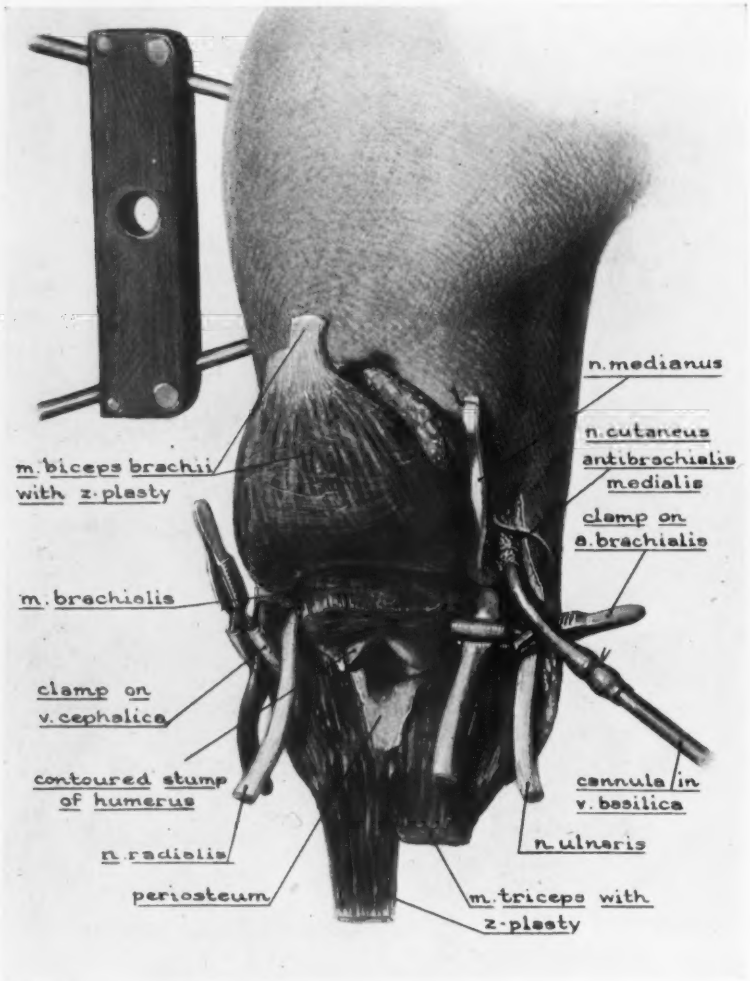

FIG. 2.—Preparation of the recipient for graft completed.

E. Surgical Procedure in Preparing Recipient for Graft:

Here, the upper Stader half pin-unit is applied first of all. Then after applying a sterile Cohen clamp, a skin incision is made exactly as in the donor. The superficial veins are cut as far distally as possible before large tributaries occur. Tendons and muscles are transected exactly as in the

donor. Nerves are cut in the distal portion of the operating field and similarly tagged, reflecting them proximally. Before cutting the deep veins and the brachial artery, these vessels should be clamped proximally with a Crile or Spivack blood vessel clamp, being careful not to injure intimal surfaces. One of the larger veins may be cannulated for transfusion purposes. Finally, the humerus is transected in exactly the same manner as in the

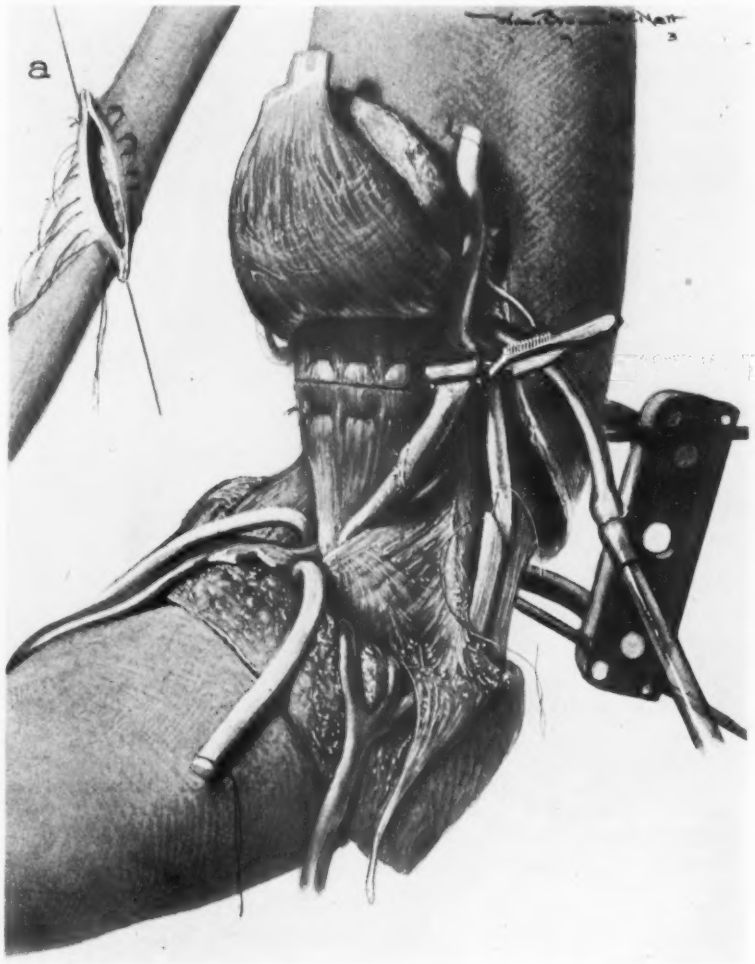

FIG. 3.—Donor graft in place on recipient, medial aspect. Closure partially completed. (a) Details of vascular anastomosis.

donor. The distal, dismembered portion of recipient can be removed from the operating field.

F. Surgical Procedure in Approximating Graft:

The donor arm must first be cut free from its cannulae and then brought into position. The Stader reduction and impaction bar should be attached

immediately. To obtain perfect alignment some trimming of the bone ends may be necessary. When alignment is obtained, bone ends are impacted and the apparatus is locked in position. As the periosteum has been carefully preserved, its edges should be approximated with fine interrupted catgut sutures.

All of the blood vessels larger than 3 Mm. in diameter should be carefully trimmed in a diagonal manner and approximated by end-to-end anastomoses,

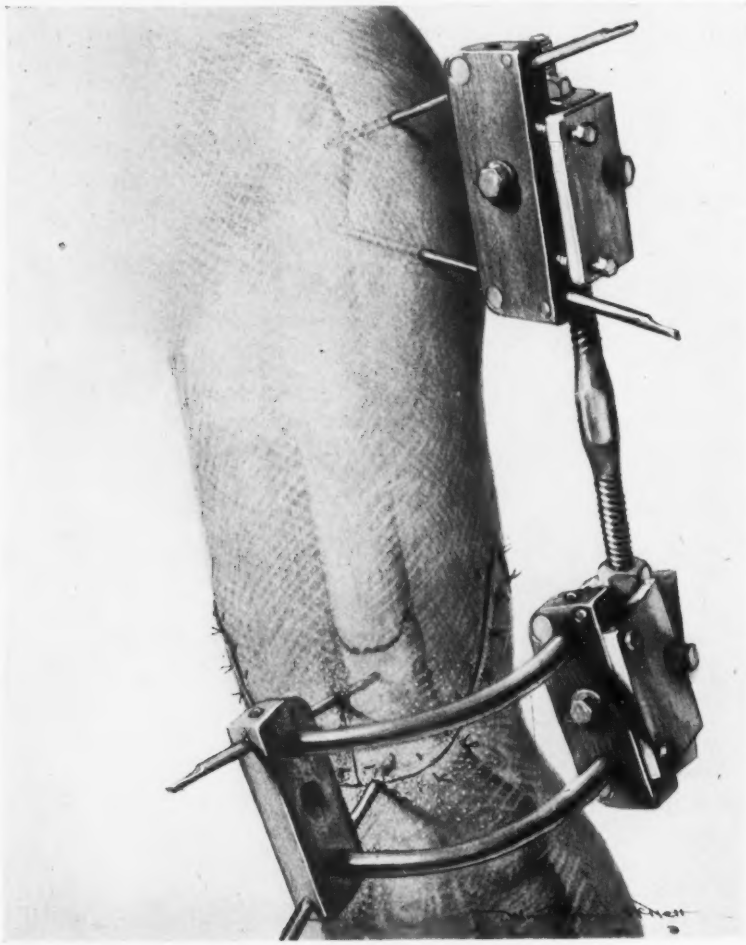

FIG. 4.—Graft approximated and wound closed, posterior aspect. Relationship of humerus to Stader splint shown.

using finest possible silk horizontal mattress sutures on a straight or curved, small, atraumatic needle (Fig. 3a). These mattress sutures, when tied, evert the vascular intima. After vessel anastomoses are completed the tourniquet should be removed and circulation restarted. When the tourniquet has been removed any leakage around anastomoses should be stopped with a con-

tinuous stitch, or interrupted stitches, binding everted vascular edges together. Other minor hemostasis may be obtained by electrocoagulation or plain catgut ties. Nerves should be trimmed diagonally with a very sharp knife or razor blade, anastomosed, similarly to the blood vessels, uniting only the epineural sheaths in an everting manner. Anastomosing these structures with oblique transections permits a larger lumen when the scar tissue contracts months later.

Special care should be observed to unite all structures and especially nerves without rotating either end about longitudinal axes. Tendons are to be repaired in the manner of a Z-plasty. Muscle bellies transected must be approximated. No attention need be paid to approximating muscles to periosteum. Intermuscular septa may be repaired if convenient. Deep and superficial fascia and skin should be approximated with interrupted fine, absorbable sutures. Sulfanilamide powder should be dusted lightly in every layer of tissues before closure. A drain may be left in the anterior portion of the elbow for 24 hours if necessary.

III. Postoperative:

A. Apply sterile vaselined gauze or alcohol dressing.

B. Roentgenograms should be taken within 24 to 48 hours postoperatively, in order to check alignment and impaction of humeral fragments.

C. The extremity should be elevated until swelling disappears.

D. Patient should be thoroughly heparinized for two or three days, until dicoumarin has evidently become sufficiently effective to prevent thrombosis. Technician should check venous clotting and prothrombin time. Clotting time should be checked every six hours while heparin is being given and should be maintained at 15 minutes or longer. Prothrombin time should be checked daily. It may vary considerably but should be watched as an index of dicoumarin action and should not be allowed to get below 35 seconds. Heparin may be combatted with protamin, and dicoumarin with transfusions if at any time necessary.

E. Medical Department to supervise administration of sulfa drugs and penicillin.

F. Physiotherapy should be started early, possibly by the end of the first week or two. Bone ends should be impacted very slightly as needed.

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STUDIES ON THE EFFECTS OF POSTURE IN SHOCK AND INJURY*

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THE SHOCK OR FOOT-UP position rather than the horizontal or the head-up position is frequently employed in the treatment of shock or potential shock, but experimental evidence of the relative effects of these positions in injured persons is lacking. Widely different opinions have been expressed by various workers in this field as to the value of the shock position, but data presented have been based chiefly on animal experimentation or postural studies in normal persons. Hill[1] recommended its use in the treatment of shock on the basis of animal experiments. Henderson and Haggard[2] studied some of the cardiovascular effects of lowering the head of a normal person to an angle of 30 to 45 degrees. They concluded that the foot-up position would not be beneficial in shock. Cannon,[3] on the basis of his observations in World War I, stated that the shock position has no beneficial effect. From observations also made in the First World War, Porter[4] strongly recommended its use. Blalock[5] advocates the shock position because of the effect of gravity in aiding venous return to the heart and in aiding the circulation of the brain. Moon[6] states that posture can have no effect since the difficulty lies in the capillaries. Asmussen,[7] and his coworkers, after extensive studies on the effect of posture upon the circulation of the normal human being at an angle of 30 to 60 degrees in the foot-up and head-up positions, state that the shock position may be beneficial in cases of circulatory insufficiency due to peripheral dilatation of vessels or to blood loss. Numerous other investigators have studied the effects of foot-up and head-up posture in normal persons at postural angles similar to those used by all of these investigators.

It was the purpose of this study to observe the effect of posture in patients with varying degrees of injury and shock both in the foot-up and head-up positions at angles similar to those produced by the shock blocks and the bed elevators used in most hospitals. These studies were continued by the senior author in collaboration with Dr. Dickinson Richards, and his associates, at Bellevue Hospital, in a study of the effect of position upon cardiac output and other functions. Some of the cases included here were observed with this group (Tables II and IV) and will be reported elsewhere in greater detail in connection with other studies.

* The work described in this paper was done under a contract, recommended by the Committee on Medical Research, between the Office of Scientific Research and Development and Johns Hopkins University.

FOOT-UP POSITION

Name and Injury			Horizontal	Foot-up	Horizontal		Horizontal	Foot-up	Horizontal	
D. W. Bleeding peptic ulcer	Arterial Pressure Mm. Hg.	Initial position change before or immediately	70/61	86/61	78/60	Repeated 40 minutes later during infusion of	85/67	93/65	89/70	Repeated 40 minutes later after total of 500
	Pulse rate per min.	after treatment begun	109	105	108	500 cc. plasma	111	105	113	cc. plasma and 500 cc. whole blood
I. M. Amputation of shoulder	Arterial pressure Mm. Hg.	Initial position change before or immediately		95/68	87/64	Repeated one hour 45 minutes later after	128/83	128/84	126/80	
	Pulse rate per minute	after treatment begun		136	136	1390 cc. whole blood	128	127	126	
M. P. Stab wound of chest. Hemopneumothorax	Arterial pressure Mm. Hg.	Initial position change before or immediately	86/66	85/64		Repeated 20 minutes later after 250 cc.	86/70	106/80		Repeated 3½ hours later after 1300 cc.
	Pulse rate per minute	after treatment begun	107	112		whole blood	112	132		whole blood
R. S. Multiple compound fractures of both lower extremities	Arterial pressure Mm. Hg.	Initial position change before or immediately		158/98	146/90	Repeated after operation during which arterial pressure fell to 80/50. Received 500 cc. whole blood and 2000 cc. normal saline	129/90	141/98	134/90	Repeated 1½ hours later after 500 cc. whole blood
	Pulse rate per minute	after treatment begun		130	130		126	125	128	
I. L. Lacerations of face	Arterial pressure Mm. Hg.	Initial position change before or immediately	80/58	92/64	86/56	Repeated one hour later after 500 cc.	116/84	117/81	122/86	
	Pulse rate per minute	after treatment begun	103	98	105	whole blood	97	95	97	
R. H. Fracture of pelvis	Arterial pressure Mm. Hg.	Initial position change before or immediately	123/86	129/89	116/82	Repeated 40 minutes later; no replacement		127/88	119/84	Repeated three hours later following operation. No replacement
	Pulse rate per minute	after treatment begun	91	89	91	therapy				therapy
S. H. Hemorrhage following gastric resection	Arterial pressure Mm. Hg.	Initial position change before or immediately	68/32	84/40						
	Pulse rate per minute	after treatment begun	144	140						
W. J. Bleeding peptic ulcer	Arterial pressure Mm. Hg.	Initial position change before or immediately	108/78	124/78						
	Pulse rate per minute	after treatment begun	100	100						
J. K. Bleeding peptic ulcer	Arterial pressure Mm. Hg.	Initial position change before or immediately	100/70	110/68						
	Pulse rate per minute	after treatment begun	126	126						

TABLE I

RAL CHANGE IN PATIENTS WITH MODERATE OR SEVERE INJURY OR HEMORRHAGE
(GROUP I)

	Hori-zontal	Foot-up	Hori-zontal
epeated 40 minutes ter after total of 500 plasma and 500 cc. hole blood	113/80 95	113/79 91	114/79 97
epeated 3½ hours ter after 1300 cc. hole blood	119/75 122	121/75 122	
epeated 1½ hours ter after 500 cc. hole blood	153/98 125	152/96 124	153/96 128
epeated three hours ter following opera-on. No replacement erapy	134/87	128/87	126/88

HEAD-UP POSITION

	Hori-zontal	Head-up	Hori-zontal
Initial position change before or immediately after treatment begun	77/60 108	75/64 118	84/67 108
Initial position change before or immediately after treatment begun	88/64 137	88/64 137	
Initial position change before or immediately after treatment begun	86/66 107	73/52 119	86/70 112
Initial position change before or immediately after treatment begun	134/94 128	122/90 135	137/96 129
Initial position change before or immediately after treatment begun			
Initial position change before or immediately after treatment begun	116/82	77/61 93	
Initial position change before or immediately after treatment begun			
Initial position change before or immediately after treatment begun			
Initial position change before or immediately after treatment begun			

	Hori-zontal	Head-up	Hori-zontal
Repeated one hour later after 500 cc. blood, 500 cc. plasma & 500 cc. normal saline	112/79 97	114/83 98	114/80 95
Repeated two hours later after 1390 cc. whole blood	130/80 100	132/79 101	
Repeated four hours, 50 minutes later after 1500 cc. whole blood	120/77 125	112/69 124	110/70 127
Repeated 30 minutes later after 500 cc. whole blood	153/96 138	141/90 142	148/96 130
Repeated four hours later following operation. No replacement therapy	136/88 104	144/90 103	

LABORATORY S
REPLACEMEN

Hematocrit Initial	Hematocrit Final	Plasma Prot Initial	Plasma Prot F
28	26	5.7	
25	41	7.2	
27	31	6.1	
52	48	7.1	
35	35	7.6	
38	33	6:8	
37	37	6:3	
19	27	4:8	
27		5:0	

ORATORY STUDIES AND PLACEMENT THERAPY

it Final	Plasma Protein Initial	Final	Total Replacement Therapy
26	5.7	5.8	500 cc. plasma 500 cc. whole blood 500 cc. normal saline
41	7.2	7:9	1950 cc. whole blood
31	6.1	5.9	1500 cc. whole blood 1000 cc. 10 percent glucose
48	7.1	7.1	500 cc. plasma 950 cc. whole blood 2000 cc. normal saline
35	7.6	6:4	500 cc. whole blood 1000 cc. whole blood
33	6:8	6:8	No treatment during study
37	6:3	6:4	2400 cc. whole blood given slowly over period of 12 hours
27	4:8	5:6	1000 cc. whole blood
	5:0		550 cc. whole blood

METHOD

Patients were seen as early as possible after admission to the accident ward in the cases of injury or upon notification of the appearance of signs of shock in postoperative cases. A specimen of blood was obtained for determination of plasma protein and hematocrit values immediately before postural studies were begun, and subsequent samples were obtained during the course of the study and at the end. In the patients listed in Tables II and IV, postural studies were begun during the latter part of the determina-

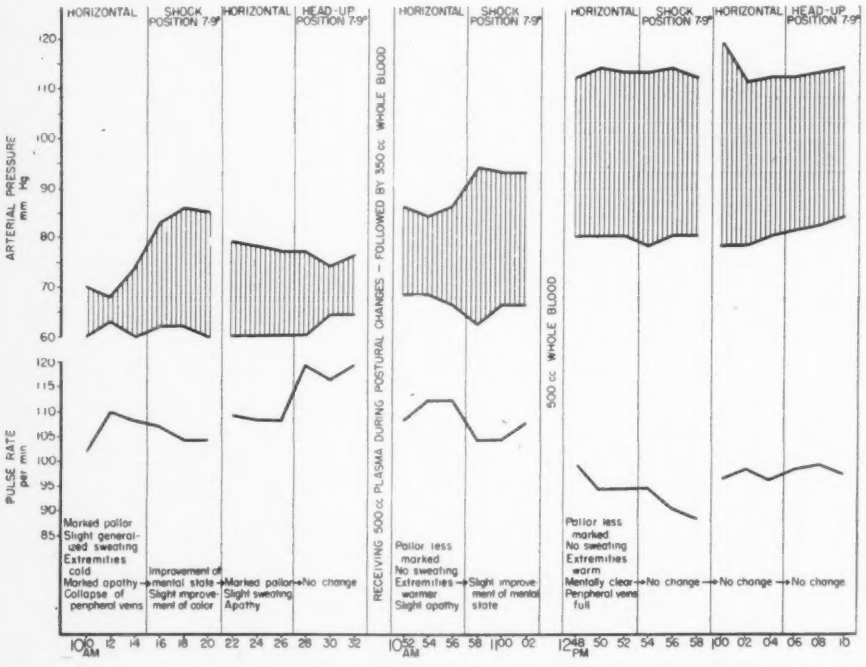

CHART 1.—D.W.: Postural studies in patient in shock due to bleeding peptic ulcer showing diminution of response to foot-up position as treatment progressed.

tion of blood volume or immediately thereafter. Symptoms and signs such as the presence or absence of sweating, pallor, the degree of consciousness, temperature of extremities to palpation, and appearance of peripheral veins were observed and reported. Three readings of arterial pressure and pulse rate were made at two minute intervals and recorded. The patient was then placed immediately in the foot-up or shock position by elevation of the foot of the bed or examining table on shock blocks measuring 12 inches in height. The resulting angle measured approximately 7 to 9 degrees with the horizontal when the examining table or bed measured 6 to 7.5 feet in length. Because of the rapidity of the changes produced in some of the patients, observations on blood pressure, pulse rate, and other symptoms and signs were made at one minute, three minutes, and five minutes after the change in posture. The patient was immediately returned to the horizontal

TABLE II

EFFECTS OF POSTURAL CHANGE IN PATIENTS WITH MODERATE OR MARKED DIMINUTION OF BLOOD VOLUME

(GROUP I)

Name and Injury	Posture	Arterial Pressure Mm. Hg. (Cuff) Brachial	Arterial Pressure Mm. Hg. (Optical Manometer) Femoral	Pulse Rate Per Min.	Blood Volume Sq. M. B.S.A. Plasma	Blood Volume Sq. M. B.S.A. Blood	Remarks
P. P.—Gunshot wound of abdomen. Exposure	Flat	46/30	33/22	62	1320	2100	Arterial pressure rose immediately when placed in shock position but immediately began to drop
	Shock	60/40	39/25	83			
	Flat	74/42	57/34	72			Repeated 1½ hours later. Had received 590 cc. blood 1500 cc. crystalloids. Bleeding into peritoneal cavity
	Foot-up	86/61	71/37	75			
	Flat	88/66	76/44	78			
	Head-up	88/60	74/43	76			
	Flat	110/58		78			Repeated 4 hours later. Had received 1000 cc. crys. solution & 1300 cc. blood. Bleeding into peritoneal cavity. 40 minutes later arterial pressure had dropped to 90/50 and other clinical signs of shock were present
	Shock	122/60		82			
	Flat	112/64		82			
	Head-up	110/63		82			
W. B.—Crushing injury of chest. Contusion of lung. Hemothorax	Flat	135/89		116	1230	2230	
	Foot-up	142/94		117			
	Flat	122/80		132	1160	1790	Repeated 5½ hours later. Had received saline slowly. Thirty minutes later patient showed evidence of clinical shock & was given 1000 cc. whole blood
	Foot-up	144/90		128			
B. S.—Laceration of wrists & neck	Foot-up	126/80		116	1350	2180	Developed clinical picture of shock 15 minutes later
	Flat	110/70		120			
	Foot-up	81 (mean)					30 minutes later. No therapy
	Flat	20 (mean)					
R. C.—Simple fract. of femur	Flat	106/63	118/66	101	1170	2270	
	Foot-up	107/65	116/64	90			
	Flat	95/64.	98/57	101			
	Head-up	101/65	110/64	102			
R. M. — Hemorrhage from esophageal varices	Flat	100/56		153	1810	2300	
	Foot-up	108/59		150			
	Flat	105/58		162			
	Head-up	101/61		164			
A. R.—Laceration of scalp	Flat		44/21	120	1030	1700	
	Foot-up		52/24	118			
	Flat	60/40	68/30	103			Repeated one hour later. Had received 350 cc. blood, 1500 cc. N. saline
	Foot-up	78/46	86/36	104			
	Flat	80/48	87/36	106			
	Flat	58/40	77/31	98	1800	2580	Repeated 1½ hours later after 100 cc. blood & 1000 cc. N. saline
	Foot-up	60/40	78/31	100			
	Flat	55/40	66/27				
W. B. — Fracture of pelvis	Flat	67/42	54/26	112	1130	1670	
	Foot-up	66/41	49/25	114			
	Flat	61/30	53/27	120			
	Head-up	60/39	47/26	120			
	Flat	78/50	62/34	134			Repeated three hours later. Had received 900 cc. blood, 750 cc. N. saline
	Foot-up	86/50	66/33	132			
	Flat	95/53	78/40	120			Repeated 30 minutes later. Had received 100 cc. N. saline. Blood volume determination done one hour after postural studies. Patient probably bleeding
	Foot-up	100/51	78/39	120	1520	2300	

FOOT-UP POSITION

Name and Injury			Hori-zontal	Foot-up	Hori-zontal		Hori-zontal	Foot-up	Hori-zontal		H zo
W. W. Laceration of neck and arm	Arterial pressure Mm. Hg.	Initial position change before or immediately	104/63	102/58	100/61	Repeated one hour later. No replacement	115/79	112/81	107/76		
	Pulse rate per minute	after treatment begun	97	96	99	therapy	85	85	89		
B. D. Compound fracture of skull	Arterial pressure Mm. Hg.	Initial position change before or immediately	120/86	124/78	124/82	Repeated six hours later following opera-	108/71	106/70	108/72	Repeated two hours later after 1500 cc.	10
	Pulse rate per minute	after treatment begun	64	62	61	tion. No replacement therapy	117	111	116	normal saline	
J. W. Compound fracture of tibia	Arterial pressure Mm. Hg.	Initial position change before or immediately	115/69	116/76	111/69	Repeated three hours later following opera-	105/62	108/64	100/65	Repeated three hours later. No replacement	9
	Pulse rate per minute	after treatment begun	75	75	78	tion. No replacement therapy	84	87	81	therapy	
G. H. Chest injury; multiple rib fractures; contusions of flank	Arterial pressure Mm. Hg.	Initial position change before or immediately	120/79	122/81	121/83	Repeated one hour later. No replacement	108/74	111/75	104/79	Repeated two hours, 45 minutes later following	1
	Pulse rate per minute	after treatment begun	105	108	113	therapy	115	111	102	operation and 500 cc. whole blood	
V. N. Comminuted fracture of femur	Arterial Pressure Mm. Hg.	Initial position change before or immediately	132/75	142/79	134/78	Repeated 40 minutes later. No replacement	133/75	135/75	128/76		
	Pulse rate per minute	after treatment begun	68	69	70	therapy	74	71	77		
J. P. Laceration of forearm	Arterial pressure Mm. Hg.	Initial position change before or immediately	88/58	85/56	85/58	Repeated 15 minutes later following collapse	46/38	44/38		Repeated one hour later. Spontaneous im-	1
	Pulse rate per minute	after treatment begun	100	99	100	in head-up position	84	84		provement following replacing in horizontal position. 1000 cc. 5 per cent glucose	
C. B. Simple fracture of tibia	Arterial pressure Mm. Hg.	Initial position change before or immediately	149/79	145/85	141/79						
	Pulse rate per minute	after treatment begun	85	89	88						
H. M. Gunshot wound of sacrum, withnerverootinjury	Arterial pressure Mm. Hg.	Initial position change before or immediately	128/86	128/86	128/81						
	Pulse rate per minute	after treatment begun	86	86	90						

TABLE III

STURAL CHANGE IN PATIENTS WITH LESS SEVERE INJURY OR HEMORRHAGE (GROUP II)

	Hori-zontal	Foot-up	Hori-zontal
peated two hours er after 1500 cc. rmal saline	105/64 102	105/60 99	103/68 100
peated three hours er. No replacement rapy	99/65 87	98/65 86	102/63 91
peated two hours, 45 utes later following ration and 500 cc. ole blood	112/74 111	114/78 105	120/85 104
peated one hour er. Spontaneous im-vement following re-cing in horizontal ition. 1000 cc. 5 per nt glucose	112/78 96	111/78 98	106/76 97

HEAD-UP POSITION

	Hori-zontal	Head-up	Hori-zontal
Initial position change before or immediately after treatment begun	100/61 99	73/51 100	79/57 91
Initial position change before or immediately after treatment begun	124/82 61	114/82 67	124/80 72
Initial position change before or immediately after treatment begun	111/69 78	104/66 77	112/73 74
Initial position change before or immediately after treatment begun	121/81 113	109/76 116	118/81 112
Initial position change before or immediately after treatment begun	124/78 70	120/77 76	138/76 72
Initial position change before or immediately after treatment begun	85/60 100	Korotkow sounds inaudible. Profuse sweating, pallor, coma	46/40 84
Initial position change before or immediately after treatment begun	141/79 88	133/75 82	140/77 85
Initial position change before or immediately after treatment begun	128/81 90	78/49 86	117/76 86

	Hori-zontal	Head-up	Hori-zontal
Repeated three hours later. No replacement therapy	107/76 89	99/65 91	103/70 91
Repeated six hours later following operation. No replacement therapy	107/72 119	106/70 119	113/74 114
Repeated three hours later following operation. No replacement therapy	102/65 81	99/64 86	108/60 85
Repeated four hours later following operation and 500 cc. whole blood	120/85 104	118/85 107	118/85 99
Repeated one hour later after spontaneous improvement and 1000 cc. 5 per cent glucose	103/74 100	99/70 97	96/65 101

LABORATORY ST REPLACEMENT

Hematocrit Initial	Hematocrit Final	Plasma Prot Initial	Plasma Prot Fin
42	39	6.6	6.
40	40	7.0	6.
42	39	6.4	6.
45	43	7.1	7.
44	38	6.7	6.
40	36	7.4	6.
42	41	7.5	7.
41	40	7.6	7.

ORATORY STUDIES AND LACEMENT THERAPY

rit nal	Plasma Protein Initial	Final	Total Replacement Therapy
39	6.6	6.2	No treatment during study
40	7.0	6.8	1500 cc. normal saline
39	6.4	6.2	No treatment during study
43	7.1	7.0	500 cc. plasma 500 cc. whole blood
38	6.7	6.1	No treatment during study
46	7.4	6.5	1000 cc. 5 per cent glucose 500 cc. plasma
41	7.5	7.5	No treatment during study
40	7.6	7.6	No treatment during study

position, after which similar observations were made at the same intervals. This procedure was then carried out in the head-up position, the same angle being used. The effects of both foot-up and head-up positions were repeatedly observed in most patients over a period of several hours. This procedure was followed in most instances, but occasionally because of therapeutic requirements, it could not be followed precisely.

Arterial pressure was determined in the patients listed in Tables I and III by the auscultatory method in the arm, and in the patients listed in Tables II and IV by both the auscultatory method in the brachial artery and the optical manometric method of Hamilton[8] in the femoral artery. In the determination of blood pressure in the arm, the arm was kept on the table or the bed parallel to the trunk in all postures. In the auscultatory method, care was taken to read the expiratory level of systolic pressure because respiratory variation in arterial pressure was frequently greatly increased. The first distinct change in Korotkow sounds was taken as the diastolic level. The heart rate was counted by arterial palpation or precordial auscultation or from the manometric tracings. Hematocrit levels were determined in duplicate with Wintrobe tubes. Plasma proteins were determined by the Barbour and Hamilton[9] method, the formula of Weech, Reeves and Goettsch[10] being used for translation of plasma specific gravity into plasma protein.

RESULTS

For convenience of description, the cases observed will be divided into two groups on the basis of the clinical and laboratory evidence of shock and blood loss.

GROUP I: The patients comprising this group showed greater degrees of injury or hemorrhage. There were 16 patients in this group (Tables I and II) and clinical signs of shock were initially present or subsequently developed in all patients except one. The most frequently observed symptoms and signs were lowered arterial pressure, increase in pulse rate, decrease in pulse volume, various degrees of sweating and pallor, cool to cold extremities, diminished filling of peripheral veins, and narrowing of the field of consciousness. In the one patient who did not show definite clinical evidence of shock, a distinct fall in arterial pressure and other signs of

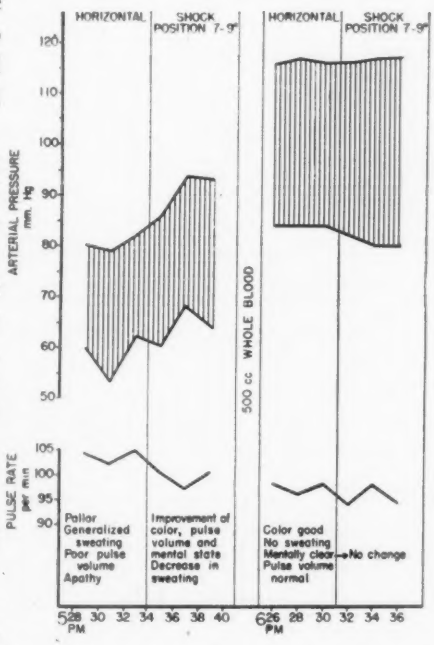

CHART 2.—I.L.: Effect of foot-up position in patient in shock due to hemorrhage from lacerations.

collapse were induced by postural change, and the nature of the injury and the blood studies indicate that he had considerable blood loss. This patient also showed a sharp decline in arterial pressure, bradycardia, sweating, and pallor during the passage of a urethral sound. In five patients the cause of shock was gastro-intestinal hemorrhage, skeletal trauma was responsible in four patients, soft-tissue laceration with hemorrhage in three, hemopneumothorax in two, gunshot wound of the abdomen in one, and severe hemorrhage occurring during a shoulder amputation in another. In the patients listed

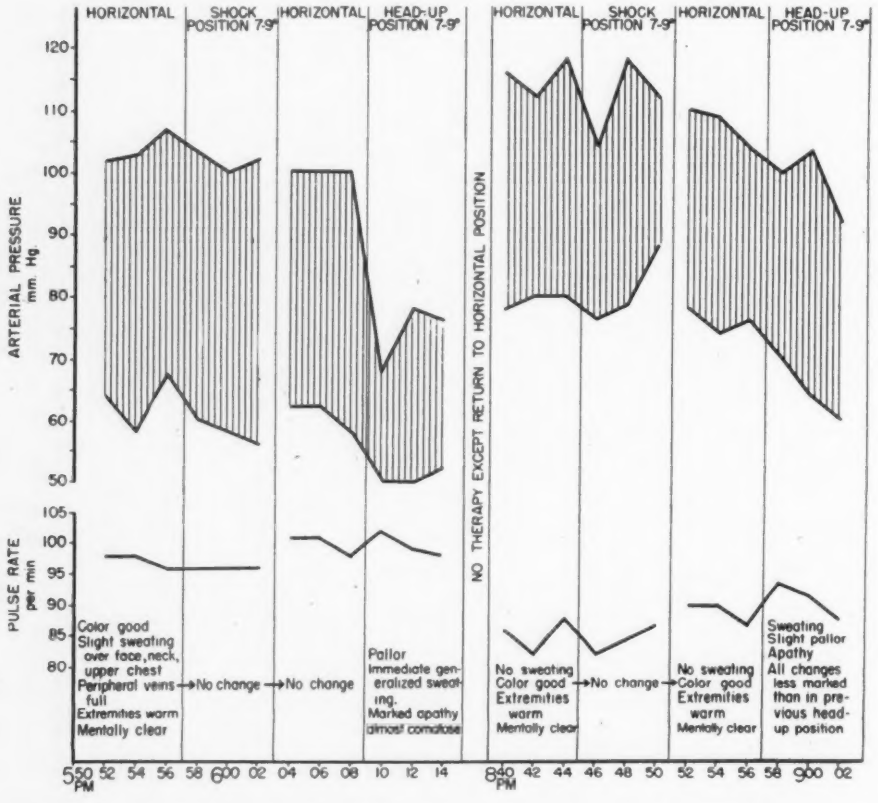

CHART 3.—W.W.: Postural studies in patient with superficial lacerations of neck and arm. Pronounced fall in arterial pressure, sweating, pallor, and apathy occurred when head-up position was assumed. No significant change was observed in foot-up position. Symptoms and signs disappeared without intravenous therapy.

in Table I hematocrit levels were lowered in all except one, and plasma protein levels were lowered in two. The hematocrit level showed hemoconcentration in one patient (R. S.) while the plasma protein level was within normal range. In the patients listed in Table II, studies in blood volume showed moderate to marked diminution.

A difference in arterial pressure in the horizontal and the foot-up position was observed in all patients of this group except two. These two later showed

a difference in arterial pressure in the horizontal and the foot-up position after the blood volume had been partly replaced. The most frequent changes were observed in systolic pressure, ranging from 6 to 22 Mm.Hg. in the brachial artery and 6 to 18 Mm.Hg. in the femoral artery. In some patients the diastolic pressure rose significantly. The pulse rate slowed in several patients and showed moderate rise in one patient. In one patient (B. S.) a difference of 61 Mm.Hg. in mean arterial pressure in the two positions was observed.

TABLE IV

EFFECTS OF POSTURAL CHANGE IN PATIENTS WITH SLIGHT DIMINUTION IN BLOOD VOLUME AND NORMAL CONTROLS

		(GROUP II) Arterial Pressure Mm. Hg.			Blood Volume Sq. M. B.S.A.	
Name and Injury	Posture	(Cuff) Brachial	(Optical Manometer) Femoral	Pulse Rate Per Min.	Plasma	Blood
R. W. – Control	Flat	118/80	134/75	79	1620	2560
	Foot-up	119/80	138/73	75		
	Flat	120/84	139/76	78		
	Head-up	118/84	147/85	78		
S. R.—Compound fract. of tibia and fibula	Flat	152/94	167/87	94	1780	3300
	Foot-up	152/90	171/91	98		
	Flat	150/90	.....	96		
	Head-up	152/88	.....	96		
A. J.—Stab wound of abdominal wall	Flat	108/74	117/71	86	1560	2690
	Foot-up	109/78	116/72	87		
	Flat	110/75	117/74	86		
	Head-up	108/80	127/79	89		
W. H. – Compound fract. of tibia	Flat	130/73	154/71	77	1580	3040
	Foot-up	130/73	150/63	72		
	Flat	128/76	150/69	75		
	Head-up	125/70	151/74	74		
S. R.—Fracture of ribs. Hemothorax	Flat	150/94	.....	96	1530	2460
	Foot-up	150/94	.....	94		
	Flat	150/90	.....	94		
	Head-up	155/94	.....	92		
I. W.—Intestinal obstruction	Flat	90/64	80/46	114	1580	2640
	Foot-up	91/61	78/41	109		
T. M. – Pneumonectomy	Flat	98/62	.....	108	1560	2600
	Foot-up	100/62	.....	116		
	Flat	97/62	.....	104		
	Head-up	99/62	.....	104		
I.N. – Control	Flat	122/73	155/73	47	....	....
	Shock	121/76	148/69	47		
	Flat	122/74	152/72	48		
	Head-up	118/74	152/80	50		

Other changes were also evident when patients were placed in the foot-up position from the horizontal or returned from the foot-up position to the horizontal position. One of the most constant and striking of these observations was the improvement in mental state when the patient was placed in the foot-up position. Color and pulse volume frequently were seen to improve and sweating to diminish. The response of arterial

pressure and other findings to the foot-up position progressively diminished as the blood volume was replaced. Because of the condition of three patients, the initial arterial pressure was determined and other observations were made with the patients in the foot-up position, after which they were lowered to horizontal position and the observations repeated.

The effects of the head-up position were observed in nine patients of this group. In only three of these did significant fall in arterial pressure occur. In three patients the pulse rate rose 7 to 12 per minute but showed no noteworthy change in the remainder of the cases. Some patients who did not show a fall in arterial pressure when placed in head-up position showed a rise to above its previous level when returned to the horizontal position. No striking effect upon other signs and symptoms of these patients was noted. The head-up position was purposely avoided in some patients because of the condition of the patient and the evidence of vasomotor lability exhibited in other positions.

Group II: Injury and blood loss were less severe in the patients of this group than in the preceding group. The clinical picture seen in the patients of Group I was not evident in this group, but some of the symptoms and physical signs were produced in several of these patients by postural change. In 14 patients (Tables III and IV) injury consisted of soft tissue laceration in three, multiple rib fracture in two, fracture of the sacrum due to gunshot wound in one, fracture of long bones in five, compound fracture of skull in one, one case of intestinal obstruction, and one patient who had undergone pneumonectomy and had received 1000 cc. of blood during operation and whose blood volume was within normal range although arterial pressure was slightly lowered. Initially, the hematocrit and plasma protein levels were within normal range in the patients listed in Table III; however, evidence of hemodilution occurred in most instances between the initial and final specimens. In only three of these patients was replacement therapy carried out during the period of study, and in two of these three, treatment was given to determine its effect on postural change. In the third, replacement therapy was given because of lowered arterial pressure which persisted for approximately 12 hours in spite of treatment. This hypotension was probably related to the large quantity of alcohol which the patient had consumed during the preceding 24 hours.

The foot-up position produced a rise in systolic pressure of 10 Mm.Hg. in one patient of this group. Examination of the injured extremity in this patient showed pronounced swelling of the entire thigh and hemarthrosis of the knee. Repeated blood studies showed hemodilution. When the patient was again placed in the foot-up position a few minutes later, no change in arterial pressure was observed. Diastolic rises of 6 and 7 Mm.Hg. were observed in two patients and a fall of 8 Mm. was noted in two others. No significant change in pulse rate was observed, and no significant change in other symptoms and signs was observed in patients of this group.

The head-up position produced striking results in some of the patients

of this group. A fall in arterial pressure occurred in seven of eight patients listed in Table III. The diastolic level fell from 4 to 60 Mm.Hg. in five patients, and the pulse rate rose 6 per minute in two patients and fell 4 and 6 per minute in two others. The greatest and most frequent changes in systolic pressure, ranging from 7 to 50 Mm.Hg., were noted in six patients. In the seventh patient (J. P.), when the head-up position was assumed, the arterial pressure dropped precipitately to an unobtainable level, the radial pulse became impalpable, the precordial sounds became weak and distant, the heart rate slowed, the patient became comatose, pallor was evident, and sweating immediately became profuse and generalized. Upon resumption of the horizontal position the patient returned to his previous condition within a few minutes. Similar signs, including pallor, sweating, and narrowing of the field of consciousness, occurred in the other patients of this group who showed the greatest fall in arterial pressure in the head-up position. They also returned promptly to their previous state upon resumption of the horizontal position. In the patients listed in Table IV the changes in the head-up position were not so striking; a rise in femoral pressure was observed in one control and in one patient in whom the blood volume was only slightly diminished. The difference in the results obtained in the two groups may be related to the fact that the patients of Table II were seen earlier and observations were made earlier after injury. Five of the eight patients in Table III and two of those in Table IV had had alcohol before injury.

DISCUSSION

These observations would seem to be of both practical and theoretical interest. The position in which an injured patient is placed is an important consideration in the treatment of injuries since pronounced changes may be rapidly produced in either mild or severe injury by only slight alteration in posture. Differences in response to postural change were observed in mildly injured and more severely injured patients. When patients with injury and blood loss of moderate severity, or patients with severe injury and blood loss whose blood volume had been partly replaced, were put in the foot-up position, signs of improvement resulted. The most consistent effects noted were an increase in arterial pressure and improvement in mental state. Other signs of improvement, including diminution in sweating, improvement in color, increase in pulse volume, and decrease in pulse rate, were less constantly observed. The response of this group to head-up position was not so striking as in Group II, although its effect was not tried in all cases. The patients in the less severely injured group showed little or no response to foot-up position in most cases, but dramatic effects were observed in some of these patients when they were placed in the head-up position, resulting in, or approaching, a state of collapse or syncope, probably from vasodilatation and pooling of blood in dependent areas and resultant cerebral anemia. The condition is similar to the vasomotor collapse produced by Weiss[11] and

his associates by postural change following the administration of sodium nitrite. Alcohol was probably contributory in some cases, but three patients with acute alcoholism, without injury, have failed to show similar response.

Apparently, a state of vasomotor instability exists in the case of injury which was not found to be present in 20 normal controls and was seen to diminish and disappear in injured patients when they returned to normal. The degree of this vasomotor instability is indicated by the fact that the cardiovascular responses in these studies have been produced by relatively small postural angles as compared with the angles used by other investigators in studies in normal persons. The fact that the patients with the most severe injury and blood loss failed to show this rapid response until the blood volume had been partly replaced, suggests that vasoconstriction is more complete or constant and, therefore, less instability can be demonstrated by postural change. The angles used in this study are more likely to be encountered in the handling of injured patients during treatment or during various diagnostic procedures.

When it was observed that a difference in arterial pressure in the horizontal and the foot-up position was associated with diminution of blood volume and was not usually seen to occur in patients with less severe injuries and blood loss, attempt was made to utilize this observation as a test for blood loss and possibly for the diagnosis of preclinical or borderline shock. The persistence of this difference in arterial pressure, though diminishing until the blood volume has been replaced, might prove useful in determining when therapy was adequate, thereby conserving blood and plasma or preventing the reappearance of signs and symptoms of shock. Considerable emphasis has been placed upon the need for early diagnosis of shock because the picture from which the clinical diagnosis is usually made is relatively late. In three patients who subsequently developed the clinical picture of shock (B. S., W.B., R.S.) a definite difference in arterial pressure was observed in the horizontal and the foot-up position before the decline in arterial pressure and other signs of shock had appeared. In another patient (P. P.), who had received treatment and in whom clinical signs of shock had disappeared, intra-abdominal hemorrhage continued and a difference in arterial pressure in the two positions was demonstrated before the fall in arterial pressure and other signs of shock developed for the second time. This difference has not been observed thus far in patients with hypotension when the blood volume is normal, as evidenced by some of the cases in the accompanying tables. It has been stated in a preceding paragraph that no response in arterial pressure and in other signs was obtained in patients with the greatest diminution in blood volume until the blood volume has been partly replaced. Differences in arterial pressure in the horizontal and the foot-up position could obviously occur in patients seen soon after injury with evidence of so-called neurogenic shock since spontaneous rises in arterial pressure may occur. Similar changes might also be seen in any other patients with wide fluctuations in arterial

pressure. Further studies will be required to prove the value of this lability of arterial pressure as an indication of borderline shock or adequacy of treatment in the case of frank shock. These studies are being carried out at the present time.

SUMMARY

1. The effect of postural change on thirty patients with various degrees of injury is described.

2. Vasomotor instability was demonstrated in injured patients that was not present in normal controls and disappeared in injured patients when they returned to normal.

3. Different effects were noted in response to the head-up or the foot-up position in mild and severe injury or hemorrhage.

4. Some of the beneficial effects of the foot-up position in the treatment of shock or potential shock as well as some of the adverse effects observed in injured patients in the head-up position are described.

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OPERATION FOR ANEURYSM OF THE HEART

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I should like to report an operation for repair of aneurysm of the left ventricle of the heart. The operation consists of grafting a segment of fascia lata, or parietal pericardium, over the aneurysm for the purpose of preventing its rupture. This is the first operation of its kind, and it is felt that it should be reported.

There is nothing of a surgical nature in the literature on cardiac aneurysm except an operation for false aneurysm by Sauerbruch.[1] He made a diagnosis of mediastinal tumor but at operation found the tumor contained blood. The sac was opened. The cavity of the sac communicated with the right ventricle by an opening which could be felt by two fingers which were introduced through the opening into the heart to control bleeding. Ligatures were placed around the sac at the site of communication and as the fingers were withdrawn the ligatures were tied and hemorrhage was controlled. Excision of the sac was carried out. There was no statement concerning the presence of myocardium in the thin sac, and I assume that the sac was parietal pericardium. If this assumption is correct it is a false and not a true aneurysm. Excision of a true aneurysm of either ventricle of the heart appears to be an impractical procedure.

EXPERIMENTS ON CARDIAC ANEURYSM

In 1934, I operated upon 16 dogs in an attempt to produce cardiac aneurysm. Some of these animals were kept for two to three years after operation but aneurysm was not produced and the experiments were not reported. Briefly, the procedure was to expose the heart and to open the auricle. A sphere of metal was introduced through the mitral valve into the ventricle. The myocardium was crushed between the sphere inside and the fingers outside the heart. It was possible to crush the myocardium to such a degree that one could recognize the color of the metal through epicardium and endocardium. The specimens showed a small amount of scar at the site of the contusion. Small deposits of calcium were also found. Pathologic manifestations of trauma were slight.[2]

Aneurysm of the human heart is usually produced by coronary artery occlusion. In our experiments in which occlusion of coronary artery was done a slight dilatation of the wall of the ventricle was occasionally observed but a well-developed aneurysm was never observed in these experiments. Hosler and Williams[3] produced an aneurysm of the right ventricle in one experiment by attaching ventricle to diaphragm. This was a true aneurysm and could be classified as a traction aneurysm.

COMPRESSION SCARS ON THE HEART *versus* LOCALIZED AND GENERALIZED DILATATION OF THE HEART

Dakin's solution when introduced into the pericardial cavity of dogs is followed by the production of scar tissue in epicardium and parietal pericardium.[4, 5] In the course of weeks or months the scar undergoes contracture and produces chronic compression of the heart.[6] The chief point of interest in these experiments concerned the physiology of compression and the surgical problems of removing compression scars. However, there is another aspect to this work which is new, which has not been discussed,

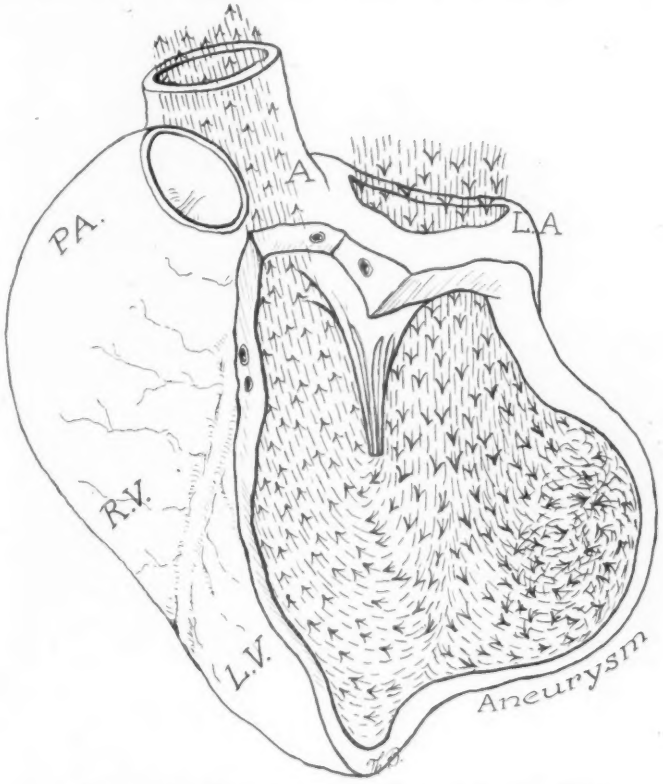

FIG. 1.—Hemodynamics in presence of aneurysm. Blood escapes into the aneurysm during systole instead of being expelled into the aorta.

and which has some significance. What I have in mind is the deliberate production of a cicatrix to support a dilating heart and also to prevent rupture of an aneurysm of the heart. Experimentally, Holman and I[7] showed that the pericardium exerted a constrictive action against acute dilatation produced by plethora. Whether a dilating heart can be helped by a supporting cicatrix on the outside of the heart is a question that cannot be answered. It deserves investigation on patients. The idea of placing a supporting graft over the aneurysm has obvious merits. In the first place, a graft can be expected to

prevent rupture of an aneurysm. In the second place, an improvement in the circulation can be expected by reducing the size of the aneurysm. In the presence of an aneurysm, the aneurysm fills out with blood with each systole. Instead of expelling the total content of the left ventricle into the aorta, part of the content escapes into the aneurysm. This is indicated in Figure 1. It is not unlike a mitral valve leak.

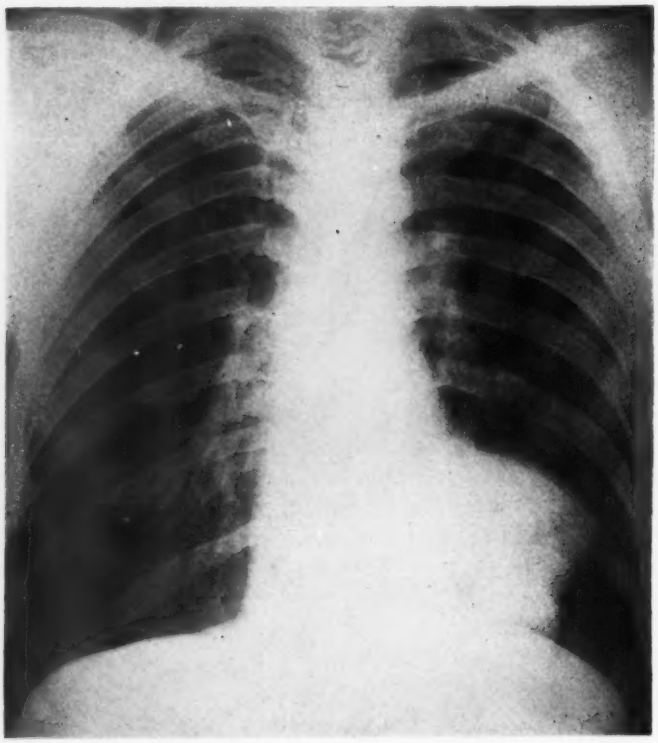

FIG. 2.—Roentgenogram of the chest showing aneurysm of the lateral aspect of the left ventricle. The excursion of the aneurysm during diastole and systole measured about 2 cm. The aneurysm bulged out as the ventricles contracted.

CASE REPORT

The patient, referred by Dr. Arthur Weihe, of Oak Park, Illinois, was a male, white, age 49. He was debilitated, and had the appearance of an old man. The patient gave a history of almost constant pain in the epigastrium. Eighteen months before admission he had an acute, severe attack of upper abdominal pain. The diagnosis of perforated gastric ulcer was made and celiotomy was performed. Two months later the patient had a second severe attack of pain in the epigastrium which radiated into the chest, left shoulder and down the left arm. The diagnosis of coronary artery disease was made. Treatment consisted of rest and administration of sedatives. Thereafter he was subject to recurring episodes of sharp anginal pain. Two months before admission to the hospital he suffered a particularly severe attack of pain. At that time a roentgenogram was taken and aneurysm of the left ventricle was demonstrated. He was referred for operation to prevent rupture of the aneurysm. A marked pulsation over

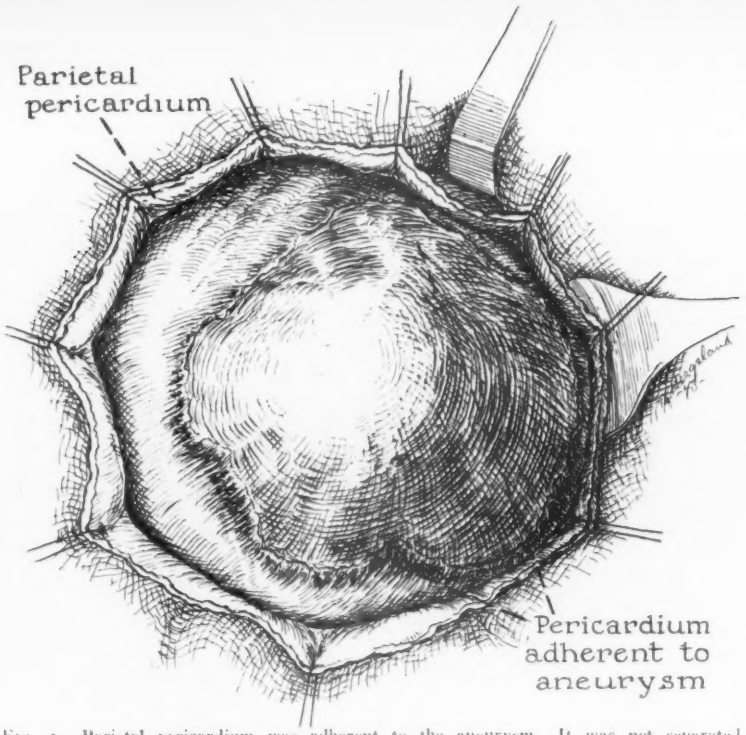

FIG. 3.—Parietal pericardium was adherent to the aneurysm. It was not separated from the heart. It was incised, leaving a patch adherent to the aneurysm.

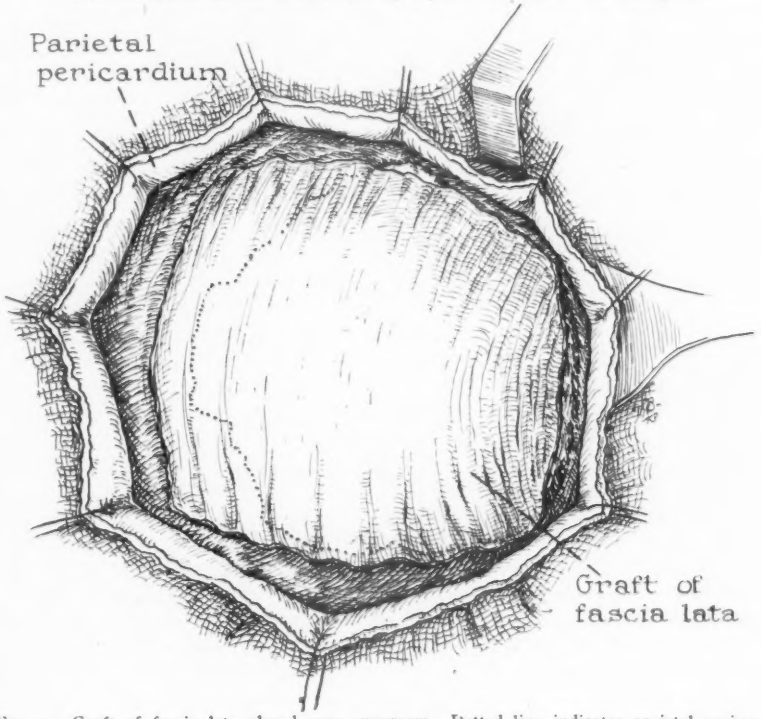

FIG. 4.—Graft of fascia lata placed over aneurysm. Dotted line indicates parietal pericardium adherent to aneurysm.

the precordium was observed. Fluoroscopic and film studies of the heart showed a large oval bulge, measuring 4 x 7 cm., in the region of the lateral wall of the left ventricle (Fig. 2). During cardiac systole this bulge became markedly distended. The aneurysm bulged out while the silhouette elsewhere became smaller. This pulsation was so marked that rupture appeared to be imminent. The electrocardiogram showed evidence of anterior and apical infarction. The sedimentation rate was normal; temperature normal; and white blood cell count normal. The patient was weak; he could not

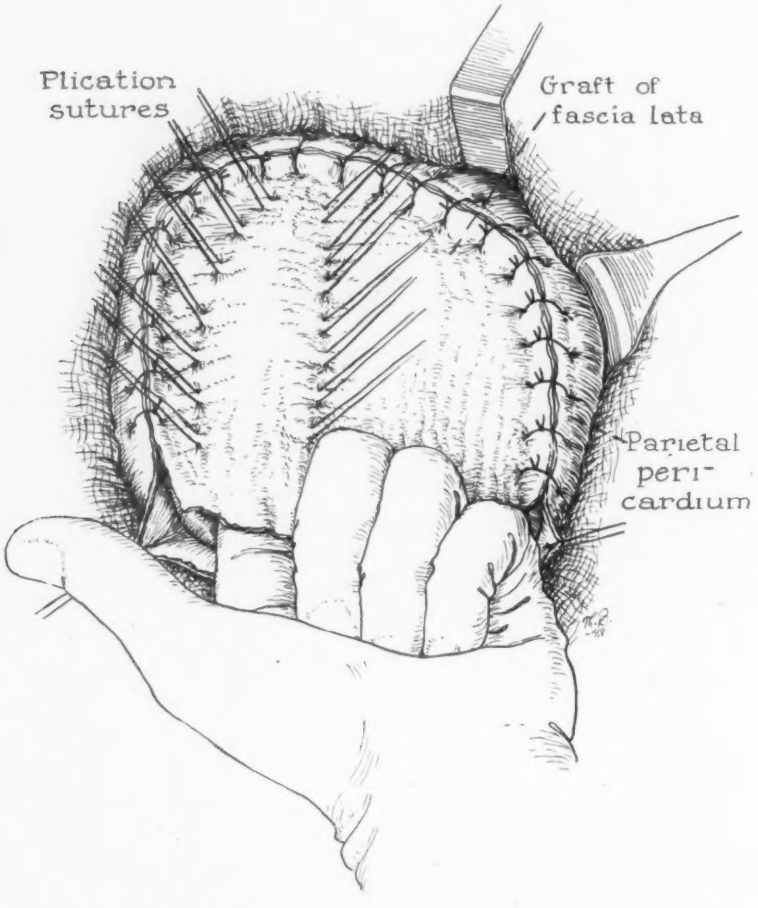

FIG. 5.—Graft of fascia lata sutured to parietal pericardium. Finger inserted between graft and heart and two rows of sutures placed.

work; he was almost bedridden. Our blood pressure determinations were practically normal, but Doctor Weihe had obtained determinations of 94 Mm. mercury, systolic.

Operation.—June 12, 1942: The fifth and sixth costal cartilages and parts of the corresponding ribs were removed and the mediastinum was opened. The lungs were adherent to the mediastinal pleura, and these adhesions were gently separated. The pericardium was adherent to the aneurysm. It was incised around the base of the aneurysm in a circle about 8 to 10 cm. in diameter (Fig. 3). A definite increase in size of the aneurysm occurred after the pericardium was cut. The pericardium offered

support to the aneurysm. The aneurysm bulged out about 4 cm. beyond the normal contour of the ventricle. The distention during systole was marked, and the possibility of rupture was present. Dakin's solution was applied by cotton pad to the surface of the aneurysm for a period of 11 minutes. A piece of fascia lata large enough to cover the aneurysm was cut and placed over the aneurysm (Fig. 4). This graft was sutured by interrupted sutures to the parietal pericardium (Fig. 5). In order to furnish outside support to the aneurysm, a series of plication sutures were placed, as shown in Figure 6. These sutures when tied reduced the size of the graft and reduced the size of the aneurysm. Closure of the wound was carried out.

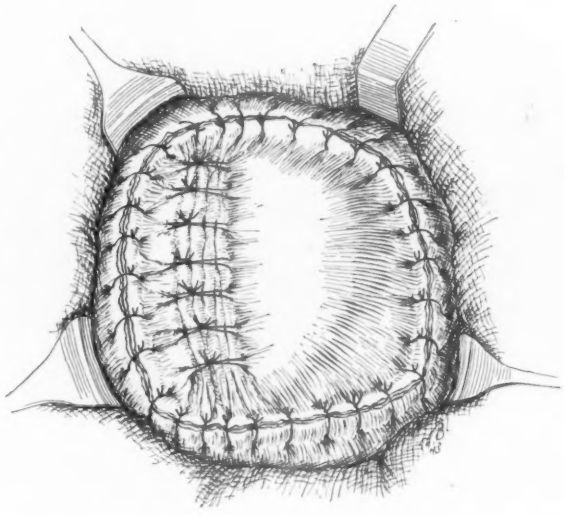

FIG. 6.—Plication sutures tied, and size of graft reduced. This afforded support to the aneurysm.

Postoperative Course.—The patient developed fever and signs of pneumonia. A small amount of serous fluid was aspirated from the chest. The wound healed *per primam.* Two weeks after operation a few cubic centimeters of serous fluid were obtained from the wound. Within a few days the fluid increased in amount and became purulent. An intercostal catheter was inserted into the left pleural cavity and a liter of pus was obtained. Dakinization of the cavity was carried out. Cerebral manifestations of confusion and disorientation appeared. The patient died five weeks after operation.

Postmortem Examination.—The fascial graft was everywhere adherent to the aneurysm. There was no evidence of infection in the graft. The graft of fascia lata was sealed to the pericardium and myocardium, and appeared as a firm cicatrix. On cross-section the graft of fascia lata and the adherent patch of pericardium appeared to be fused with the cicatrix of the aneurysmal wall. The latter was only a few millimeters in thickness. A mural thrombus, measuring 1.7 cm. in its greatest thickness, was found in the aneurysm (Fig. 7). There was no evidence that any of the thrombus had been swept into the brain. The myocardium was extensively degenerated into scar tissue. This cicatrix involved anteriolateral aspect of left ventricle and part of the interventricular septum. The descending ramus of the left coronary artery was completely occluded. The right coronary artery showed some changes but it and the circumflex ramus of the left coronary artery were patent. Other findings were the pleural empyema cavity which was drained; arteriosclerosis of aorta and cerebral arteries; and encephalomalacia of the cerebral cortex and thalamus.

In reference to application of this operative procedure for aneurysm of the heart, one can raise the question as to whether the attempt is worth while. In this patient the emaciation, the sclerotic changes in aorta and cerebral vessels, and the mural thrombus within the heart were factors that would make any operative procedure almost futile. In my opinion this operation

FIG. 7.—Cross-section of heart. Note graft and silk sutures. The fascia lata and parietal pericardium are fused with the cicatrix of aneurysmal wall. The wall is extremely thin. Note thrombus in the ventricle.

would offer fair chance of success if it were performed upon a patient who did not show such extensive degenerative changes. The operation, in itself, is not a serious or drastic procedure.

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INFECTED DISSECTING ANEURYSM OF THE ILIAC ARTERY FOLLOWING ARTERIOVENOUS FISTULA OF THE FEMORAL VESSELS*

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HUNTER, in 1762, called attention to the dilatation of the proximal portion of the artery in his first case of arteriovenous aneurysm. Since that classical report dilatation of the artery to a varying extent has been reported frequently. From a study of the literature one might assume that its frequent mention would warrant the belief that dilatation of the artery entering an arteriovenous aneurysm is an essential part of the pathology. However, in a most painstaking study by Callender[1] of 447 reported cases of arteriovenous fistula dilatation was noted only in 57, or 12.7 per cent. Undoubtedly it was present but not noted in other reported cases but its constancy in arteriovenous aneurysm cannot be taken for granted. The late Mont Reid, a great master in the field of arteriovenous aneurysm, believed that dilatation of the artery occurred only after the lapse of years.[2] This was true in his experimental animals. Of the six clinical cases which he reported dilatation was seen only in those of long duration.

According to Holman's view,[3] based largely on extensive experimentation, proximal dilatation of the artery is to be explained on purely physiologic grounds. It is dependent primarily on an increase in the total volume of the circulating blood and more particularly on an increase in blood flow through the fistulous zone. This increase is one of the compensatory changes necessary to rectify the fall in blood pressure incident to the greatly decreased peripheral resistance in the presence of a fistula. This theory implies dilatation of the artery in all instances of arteriovenous aneurysm, at any rate in all instances of long duration, and this does not appear to be the case.

Regardless of the incidence of, and the theory to account for, proximal dilatation of the artery, extraordinary dilatation of the artery entering the aneurysm is rare. This communication is concerned with such dilatations and their significance. It, therefore, is appropriate to refer to the reported cases. In Callender's list are four cases, all from an early period, and all fatal. The first is Beaumont's,[4] in which the superficial femoral artery was greatly dilated, admitting two fingers. The common femoral and external iliac arteries throughout their course were equally dilated, somewhat thinned, but otherwise healthy. In Fitzgerald's[5] case, reported in 1878, the popliteal artery above the arteriovenous aneurysm was somewhat dilated, the femoral artery was greatly dilated, but the external and common iliac were much

* Read before the New York Surgical Society, April 12, 1944.
Received for publication March 25, 1944.

more so, having a circumference three times that of the opposite side. The dilatation terminated abruptly at the upper end of the common iliac artery in a thin-walled prominent sacculus. The elongation and tortuosity of the dilated arteries were as prominent as the dilatation. The third case was reported by O'Grady.[6] There was a remarkable dilatation of the external iliac artery, which approached the abdominal aorta in size. Resembling a sausage, it was distended and tortuous, suggesting a coil of small intestine. Lucas-Championnière's[7] case, also, was one of remarkable dilatation of the femoral and iliac arteries.

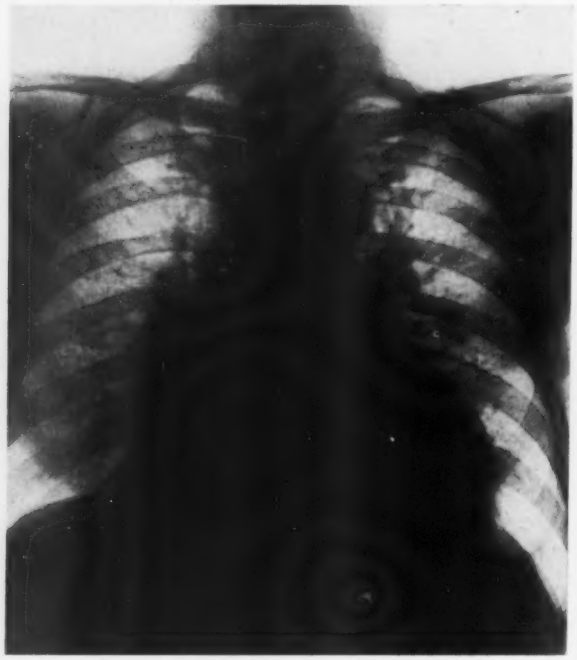

FIG. 1.—Case 1: Roentgenogram showing the enlargement of the cardiac shadow.

It is impossible to ascertain what rôle was played by the marked or extreme dilatation of the arteries in the reported cases. Indeed, no particular clinical significance appears to have been ascribed to any degree of dilatation of the proximal artery, despite the fact that thinning of the wall is as characteristic as tortuosity and dilatation of the vessel. Although there are undoubtedly other reported instances, I have found only one case report in which the artery was described as presenting a problem at the time of operation. Reid and McGuire[8] report a case in which the femoral artery just proximal to the arteriovenous aneurysm "was the largest artery Reid had ever ligated," more than one inch in diameter. Its wall was so thin that blood actually oozed through it proximally when the ligature of tape was tied. The bleeding stopped under gentle pressure with gauze.

The possible problem arising out of the more severe forms of dilatation is to be seen in the case herewith reported (Case 1), which is not intended to detail all the features of interest.

Case 1.—Mt. Sinai Hospital No. 490586: I. H. S., age 58, was admitted in mild heart failure of short duration, with a history of swelling of the left leg of three weeks' duration, and with an obvious popliteal arteriovenous aneurysm. The latter was the result of a stab wound sustained 40 years before. There were few if any symptoms referable either to the aneurysm or the cardiac status over this period of many years. The outstanding local feature, in addition to the usual evidence of popliteal arteriovenous aneurysm, was an enormous tortuous dilatation of the femoral artery throughout its course. This is illustrated in the diodrast visualization of the artery (Figs. 1 and 2). There also is to be noted diffuse calcification of the vessel (Fig. 3). The cardiac lesion appeared to be a combination of mitral stenosis and insufficiency (Fig. 4). Because of fever which was present without obvious cause, a blood culture was taken, which revealed diphtheroid bacilli.

The possibility of the aneurysm as the source of the bacteremia was entertained, particularly in view of the extraordinary case reported recently from our surgical service by Touroff.[9] It was also thought that the cure of the aneurysm might improve the cardiac status as it has in other cases. Accordingly, an obliterative endoaneurysmorrhaphy was performed. The interior of the sac disclosed no vegetations. The operation was uneventful.

The postoperative course was uninfluenced both as regards the bacteremia and the size of the heart. There was no recurrence of the aneurysm. The possibility remained that the enormously dilated femoral artery might contain vegetations from which the bacteremia was derived; and act as the aneurysm might have done to produce heart failure. Three weeks after aneurysmorrhaphy the femoral artery was excised under local anesthesia. The interior of the artery disclosed no vegetations and it was, therefore, assumed that a vegetative *endocarditis* was the source of the bacteremia.

The postoperative course again appeared to be uninfluenced by operation. Death occurred suddenly a week after operation, apparently the result of a cerebral vascular accident. The features of the autopsy (P. M. No. 12247) of special interest were:

Hypertrophy and dilatation of all chambers of the heart, subacute bacterial endocarditis involving the aortic valve (from which the same diphtheroid organism was

FIG. 2.—Case 1: Roentgenogram showing the calcification in the wall of the greatly dilated femoral artery.

grown as in the blood stream), and dilatation of the iliac artery on the affected side (as well as some general dilatation of the aorta).

The case of infected dissecting aneurysm (or infected hematoma in aneurysmal dilatation) of the iliac artery following arteriovenous fistula of the femoral vessels, is as follows:

Case 2.—Mt. Sinai Hospital No. 502552: W. L., a physician, age 48, was admitted, March 8, 1943, with the history of a bullet wound in the lower left thigh sustained when eight years old. Thereafter, there was always some slight swelling of the left leg.

FIG. 3 FIG. 4

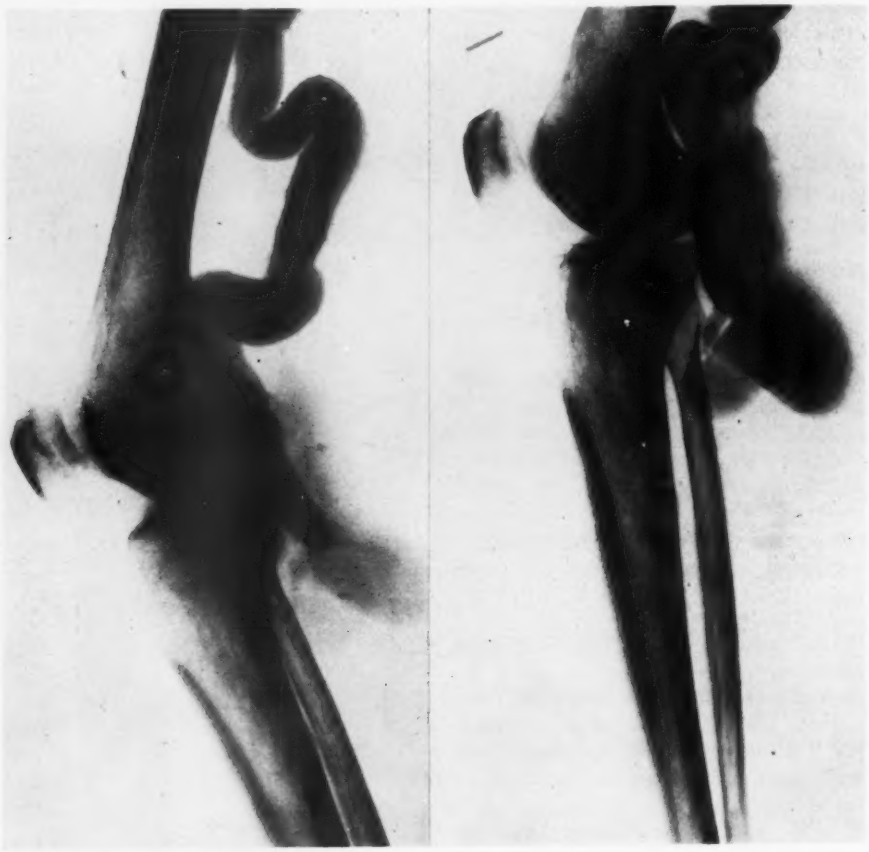

FIG. 3.—Case 1: Roentgenogram following injection of diodrast into the femoral artery. Tortuosity and dilatation of the femoral and popliteal arteries are pronounced.
FIG. 4.—Case 1: Roentgenograms taken immediately after that shown in Figure 3. The saccular dilatations between artery and vein and the dilatation of the popliteal vein are revealed.

Throughout many years he was entirely symptom-free, and engaged in active practice. Excessive pulsation in the left inguinal region and thigh had always been noted. Apparently the only symptom that led to an operation upon the arteriovenous fistula, in 1934, was an episode of pain in the posterior aspect of the thigh (in 1933). Operation was performed by J. deJ. Pemberton of the Mayo Clinic, in 1934, who kindly provided data which are abstracted as follows:

Enlargement of left leg with distention of the superficial veins. Thrill and bruit over the arteriovenous fistula, cardiac hypertrophy. Blood pressure 120/60. Operation consisted of excision of a segment of the left femoral artery and vein, which included the arteriovenous fistula (opening about 1 cm. in diameter).

The arteriovenous aneurysm was cured, and there is not the slightest trace of any recurrence. Apparently it was assumed that the pulsating mass in the inguinal region would recede, but it remained unchanged. In recent years there were occasional cramps in the left calf on brisk walking. There have been no other symptoms.

Five days before admission dull ache in the left inguinal region began, with feverishness and anorexia. The aching pain increased gradually in intensity. The day before admission there was a five-minute chill.

On admission, the cardiac and general physical examination revealed no abnormalities. Approximately normal cardiac contours were noted in the chest films. The incisional scar at the site of repair of the arteriovenous aneurysm was free from any pulsation, and established that the aneurysm was cured. In the left inguinal and iliac region was a prominent, sausage-like pulsating mass with redness of the overlying skin (no local medication had been applied). Forcible pulsation was visible and palpable. The area of aneurysmal dilatation, which obviously involved the iliac artery, appeared to extend upwards to involve the whole length of that vessel (including the common iliac ?). The left leg was larger than the right, with superficial veins somewhat engorged. In the upper thigh the circumference on the right side was 50 cm., on the left, 54.5 cm. At the lower thigh, the right measured 40, the left 43 cm.

The study of the circulatory dynamics was made by Dr. W. M. Hitzig. With an initial venous pressure of 6 cm. there was no rise on compression of the right upper quadrant. The circulation time of "arm-to-tongue" (decholin) was 11 seconds. Thus, the cardiovascular dynamics were normal.

The diagnosis and decision as to procedure were arrived at after a short period of observation. There was persistent pain in the thigh and leg, and persistent warmth and redness over the inguinal mass. On the day of admission there was a five-minute chill with slight rise in temperature, but the next day a fifteen-minute chill occurred, with temperature of 104.6° F. A blood culture was negative; Wassermann negative.

Operation was performed on the second day after admission, with the diagnosis of an infective lesion within the greatly dilated iliac artery. A liberal extraperitoneal approach exposed the mass from the bifurcation of the aorta to the inguinal ligament. The lower portion of the incision was extended to the thigh in order to expose the upper portion of the femoral artery. The peritoneum was exposed and stripped away to the midline. The cellular tissue overlying the mass was acutely inflamed, edematous, and adherent. The mass was a pulsating, enormously dilated external and common iliac artery. It extended upwards to within 3 or 4 cm. of the bifurcation of the aorta, where it narrowed abruptly to the normal size of the common iliac artery. Similarly, at the lower end the mass narrowed down to an apparently obliterated femoral artery just below Poupart's ligament. The shape and size of the mass are best seen in Figure 5. On palpation, the sausage-like mass appeared to transmit pulsation although some measure of through pulsation could not be excluded. Only towards the end of the dissection was the iliac vein identified as a thick-walled, collapsed, tape-like structure adherent to the deep surface of the dilated artery.

The aneurysmally-dilated artery was removed completely. Under good visualization the vessel was exposed a short distance below the bifurcation of the aorta. It was severed between stout silk ligatures at the point of narrowing immediately above the dilated sac. The release of the sac was carried out from above downwards by sharp and blunt dissection through a good plane of cleavage from an encasing inflammatory connective tissue layer. No significant vessel was encountered until the inguinal ligament was approached. A large arterial trunk, which may have been the internal iliac artery,

was there encountered and was severed between ligatures. The release was continued a short distance on the thigh below the termination of the mass, at which level the old operative field was entered. There appeared to be complete obliteration at the point of severance of the femoral artery. The wound was closed in layers.

The specimen proved to be a dissecting aneurysm of the iliac artery. It was 16 cm. long, with a circumference of 15 cm. at its widest proximal portion, and an average of 11 cm. over the distal portion. The sac terminated below in the completely

FIG. 5

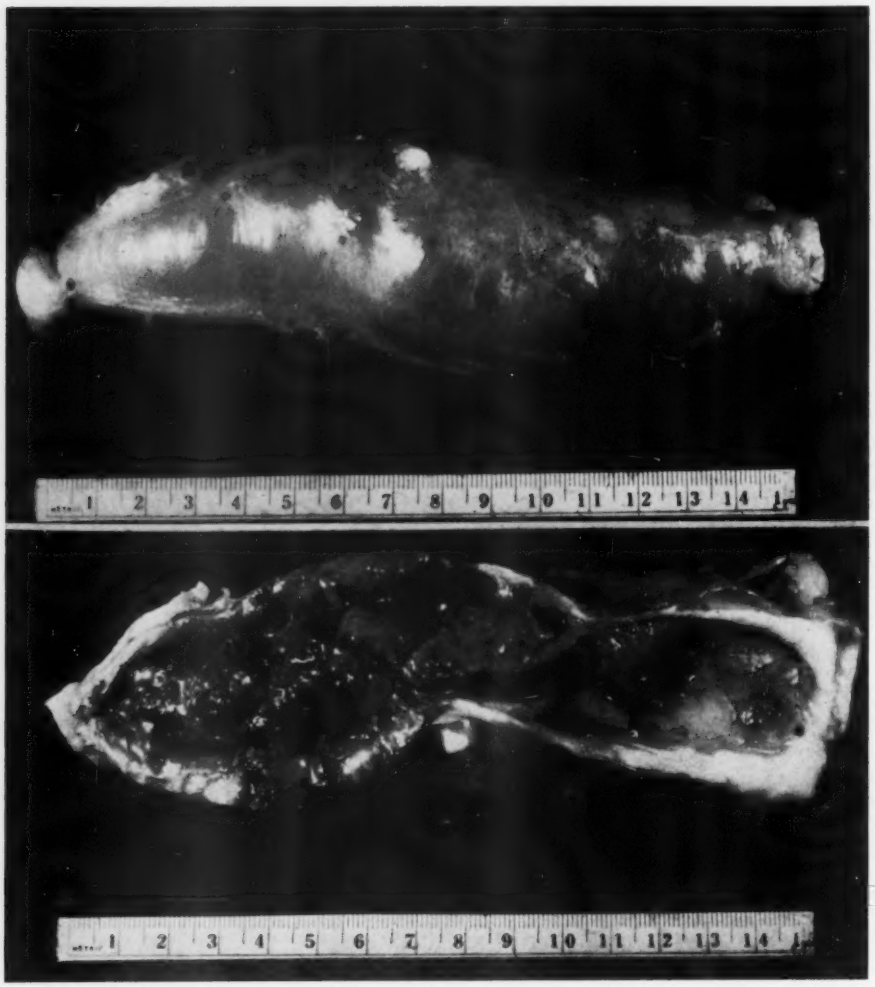

FIG. 6

FIG. 5.—Case 2: Photograph of the excised aneurysm of the iliac artery.
FIG. 6.—Case 2: Photograph of the specimen opened, showing a dissecting aneurysm, with an adherent, infected blood clot.

obliterated femoral artery with a grayish-white homogeneous tissue laid down in concentric layers. The lumen was occupied by blood clot. In the proximal portion the thrombus was pinkish-gray, adherent, and partly organized. A partial lumen could

be identified. In the distal 7 cm. there was complete occlusion, chiefly by adherent grayish material. Part of this old, obviously infected clot was semisolid and free. The intima, to which the blood clot was for the most part loosely adherent, was continuous in one area and in another area (as seen in Figure 6) was detached by the blood which has dissected beneath it. Calcification could be felt beneath the intima. The wall of the artery measured between 2 and 3 millimeters.

The microscopic examination revealed thinning, atrophy, and arteriosclerosis of the wall of the artery, with infected thrombus containing gram-positive cocci (culture taken at the time of operation was reported enterococcus). The microscopic examination of the adjacent vein confirmed the impression derived from gross examination, namely, phlebosclerosis with complete obliteration of the lumen by fibrosed thrombus.

The postoperative course was uneventful. The temperature reached normal levels by the third day and remained so thereafter. There was increased warmth over the left leg for a period of about ten days, presumably due to the severance of sympathetic fibers. The blood pressure remained unchanged. The wound healed *per primam*. The patient left the hospital about three weeks after operation. There was some weakness in the left leg for several weeks thereafter. There has been no appreciable edema, and there is now (one year after operation) no difference in size between the two legs. The patient remains quite symptom-free.

DISCUSSION.—These two cases provide a commentary on some of the statements which have been made concerning dilatation of the artery proximal to the aneurysm. In both instances the traumatic aneurysms date to childhood, and thus offer support to the view that extreme dilatations probably depend on the duration of the lesion rather than the size of the arteriovenous fistula. In neither case can the enormous proximal dilatation be said to have contributed to the heart failure. The first patient was symptom-free throughout the many years in which he carried both the aneurysm and the dilated femoral artery. The second patient presented the characteristic reduction in the size of the heart after the operative cure of the aneurysm. The heart remained of normal size despite the presence of the ectatic iliac artery over a long period of time. On the other hand it is noteworthy that the dilatation did not recede, as might have been anticipated, after the cure of the aneurysm had been achieved. No clinical significance can, therefore, be attached to the mere presence of the extreme dilatation of the proximal artery in these two cases.

In the first case, operation was performed primarily because of the possible source of bacteremia from vegetations within the aneurysm or the dilated proximal artery. This proved to be incorrect, for the source was found to be within the heart. However, the same assumption might prove to be correct in another case. In the second case, the source of infection was the infected thrombus within the dilated iliac artery. Although the blood culture was negative, the chills and fever before operation not only indicated a patent blood stream communicating with the aneurysm but also the likelihood of a positive culture if operation had not intervened.

Concerning the possible usefulness in circulatory dynamics of the dilated proximal artery these two cases appear to demonstrate that, insofar as extreme dilatations are concerned, no desirable feature can be ascertained. The

dilated atrophic channels appear to be nothing more than blood sewers calling for additional cardiac effort to push their contents along. On theoretic grounds, it can be said that their elimination should improve cardiovascular dynamics. On the basis of the reported case it can be said that their presence comprises a menace.

CONCLUSION

Severe grades of dilatation of the proximal artery in cases of arteriovenous aneurysm of the popliteal or femoral vessels should be treated by excision of the dilated artery. In the presence of infection within the ectatic artery excision is imperative.

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LIGATION OF THE ABDOMINAL AORTA

CASE REPORT

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THIS CASE seems worth reporting because of the small number of aortic ligations on record.

Case Report.—The patient was a man, age 61. There was nothing of interest in his past history, except an attack of vertigo four and one-half years before, followed by deafness.

He was first seen at this hospital, December 2, 1942, complaining of severe epigastric pain which had come on suddenly two days before, and had been present without respite ever since. There was no history of any previous gastro-intestinal symptoms and no radiation of pain.

Physical examination showed a well-nourished man in evident pain. No important abnormalities were evident except in the abdomen. The heart showed no murmurs, and the rate and rhythm were regular. Blood pressure 140/90. There was no abdominal rigidity, but there was marked epigastric tenderness, and a mass, which was thought to pulsate in an expansile manner, was felt below and somewhat to the left of the umbilicus. All deep reflexes seemed normal.

Urine: Sp. gr. 1.018; no albumin or sugar; and no red blood cells or pus. Blood showed hemoglobin determination of 13.1 Gm. per 100 cc. blood, red blood cells 4,200,000, leukocytes 6,150. Kline exclusion test for syphilis was negative.

Electrocardiogram, December 17, 1942, showed large Q waves in leads II and III, with elevated ST segments in leads II and III, and deeply inverted T waves in leads II and III. Precordial lead CF V showed depression of the ST segment. The changes were believed to be typically those of an acute posterior myocardial infarction. In addition, a tentative diagnosis of abdominal aortic aneurysm was made.

He remained in the hospital 21 days. During this time his blood pressure remained about where it was on admission. He was discharged on December 26, 1942, and returned for observation on January 30, and February 20, 1943. He seemed to be doing well. His blood pressure had risen to about 170/110.

On March 3, 1943, following unwise exertion, he had severe abdominal pain, collapsed, and was brought to the hospital the next day. He had diarrhea, urinary frequency, low abdominal pain, and his blood pressure was 50/?.

Below the umbilicus, and to the left, a pulsating mass was noted about the size of a large orange; there was no bruit. His pain ceased, and his blood pressure rose to 110/70 on March 5. His urine showed red blood cells, albumin and granular casts.

On March 6 there was another episode of lower abdominal pain, and his hemoglobin was found to be 7.9 Gm. per 100 cc. blood. The patient seemed to be in shock.

On March 7 the condition remained about the same. The hemoglobin was 6.2 Gm. per 100 cc. blood, and the mass had increased in size, filling the left side of the lower abdomen and extending along the flank.

The possibility of a ruptured ectopic kidney was suggested, though the diagnosis thought to be more probable was rupture of an abdominal aneurysm.

The patient's condition was desperate and it seemed best, in view of the possibility,

slight as it was, of there being a ruptured kidney, to give him the benefit of the doubt and explore the abdominal tumor. At this time his blood pressure was 105/70; and the hemoglobin was read at 6.2 Gm. per 100 cc. blood. He was prepared by giving a transfusion of about a pint of blood. When taken to the operating room, his blood pressure was 110/70. Arrangements were made to start another transfusion at the beginning of the operation. The patient was laid slightly on the right side with the left side supported by pads, raising it a few inches from the table.

Operation.—Under ethylene gas, an incision was made similar to the continuation of the ordinary incision for exposing a kidney, and ran from near the tip of the twelfth rib down into the inguinal region. The fibers of the external oblique muscles were separated, and those of the internal oblique and transversalis cut across. A great mass of clotted blood was found and evacuated. The viscera were pushed upward and what was evidently a ruptured aneurysm exposed. Up to this point there had been no fresh bleeding, but it now started again. Quickly, using the index finger, the aorta above the aneurysm was dissected, encircled, grasped and compressed, completely controlling the bleeding. There was found to be a rather long tear in the anterior surface of the aneurysmal sac, which contained blood clot, and two openings, which were supposed to be the rough sclerotic orifices of the common iliacs, could be palpated. After due consideration, there seemed no alternative other than to ligate the aorta, which was done with two layers of ribbon gut. Two cigarette drains were then inserted to the region of the aneurysm and the wound rapidly repaired. The duration of the operation was a little less than one hour, during which time the patient received another pint of blood by transfusion. His condition at the end of the operation was about the same as at the beginning. No pulsations could be felt in any of the arteries of the leg.

Postoperative Course.—That evening, two hours postoperative, his blood pressure was 148/76, pulse 150.

The following morning his blood pressure was 140/70, pulse 110, and the patient recognized his attendants. His legs were cool, but not cold, nor discolored, but he did not move them, and there was no pulsation in any arteries.

Suddenly, at 11:45 A.M., he developed Cheyne-Stokes' respirations, his pulse and blood pressure became imperceptible, and he died 20 minutes later. There was no sign of hemorrhage along the drains.

Unfortunately, his sister (his only relative), though she was a trained nurse, would not give permission for an autopsy, in spite of many efforts made to persuade her.

COMMENT: We should like to have learned the exact cause of death, which may have been pulmonary embolism or coronary thrombosis. We did not think it was due to fresh hemorrhages from the aneurysm. We should also have liked to have observed the site of the ligation, for it would have been better judgment to have used cotton tape instead of an absorbable ligature for such a large vessel.

In 1940, Elkin reported on all cases of ligation of the aorta reported up to that time. He found 13 instances of complete ligation. Only one of the patients survived the operation. Five lived 24 hours or longer; one, 65 hours. Our patient survived the operation 18 hours.

Matas reported a patient who survived ligation one year and five months, dying then from tuberculosis, but this was not a complete ligation, for the aorta was found to be patent at autopsy.

Brooks reported a patient who survived ligation for three months, dying then of intestinal obstruction. He had returned to his work as a truck driver

in the interim, apparently without any impairment of circulation below the ligature. In this case, however, the aneurysm, of luetic origin, was very large and of long duration, and there had been development of collateral circulation previous to the ligation.

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SURGICAL ASPECTS OF PANCREATIC FISTULA*

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THE EVER WIDENING SCOPE of abdominal surgery has encompassed within the past twenty years the intriguing and difficult operative procedures upon the pancreas. A common sequela of such operations has been the advertent or inadvertent creation of a pancreatic fistula associated with the host of problems attendant upon such a result. Opportunities to study and record the effects of the continued loss of pancreatic fluid upon the human have been rare although the problem has been given detailed attention in the experimental animal. It has been our privilege to have under observation for varying periods of time three patients with pancreatic fistulae of varying degrees of severity, one of which was producing as much as 1,700 cc. of pancreatic juice a day. This amount is in great contrast to the quantity of pancreatic juice lost in many of the cases reported in the literature, where the average ranges from 250 to 500 cc. in 24 hours.

An unusual privilege was afforded to make observations in one of these cases. The amount of pancreatic fluid secreted was large enough so that conclusions regarding the various aspects of flow were of great value. Opportunity was thus afforded to study:

1. The results of the continued loss of pancreatic fluid upon plasma electrolytes.

2. Replacement therapy to correct deficiencies produced in the plasma electrolyte pattern resulting from the loss of pancreatic fluid.

3. Drugs available to slow the flow of pancreatic juice.

4. The creation of a mechanical device to prevent irritation of the skin from pancreatic juice.

For purposes of orientation it might be well to add here, parenthetically, that a number of causes may produce a pancreatic fistula. Probably the most common etiologic factor is drainage of a pancreatic cyst, as marsupialization is the usual procedure in the surgical treatment of this condition. A fistula may follow operation for acute inflammatory conditions or, in not so rare instances nowadays, may be the result of a stab or gunshot wound of the abdomen. Operative injury to the pancreas with the creation of a fistula may follow surgery either upon that particular organ or upon one of the adjacent structures.

As far as treatment of such fistulae is concerned, it is our feeling that all such fistulae cannot be treated in the same manner. Even as other specific surgical conditions, these demand individual variations in therapy. We are certain that the patient should be restored to a metabolic normal before the

* Submitted for publication May 4, 1944.

idea of surgery is entertained. Then, an additional period of observation is indicated to permit spontaneous closure. If, after a reasonable period, such a closure does not occur, surgical intervention is justified. The three case reports which follow exemplify this concept.

One patient from this small group is illustrative of the most severe type of change in electrolyte and nutritional balance which may be seen resulting from any abdominal fistula. He is a 25-year-old white male, who sustained a severe perforating wound of the abdomen from a shell fragment. Details of the immediate care are lacking, but the patient does mention receiving 250 cc. of plasma preoperatively. Available records indicate that when celiotomy was performed on the day of injury a small stellate laceration of the upper surface of the liver, perforation of the gallbladder, laceration of the stomach and a retroduodenal hematoma were found. Although specific mention of pancreatic damage was not made on the brief operative note, injury was present, as proven by the subsequent development of an external pancreatic fistula. The various injuries were sutured, although the hepatic laceration was not disturbed, as a hemorrhage from it was not seen. His postoperative course was somewhat stormy. Effective supportive treatment in the form of suction siphonage and sodium sulfathiazole intravenously, combined with excellent surgical care, carried this individual through a rather dangerous period.

The first mention of a pancreatic fistula was made on the 13th postoperative day. Five days later a catheter was inserted into the tract and negative pressure by means of a water-suction device applied. Subsequently, considerable maceration of the skin surrounding the site of drainage was noted.

Laboratory data obtained at this time were of more than usual interest: A moderate degree of anemia was associated with a somewhat severe leukocytosis. Collection and examination of the fluid draining from the fistula proved that it was of pancreatic origin. The diastase value of this fluid was reported to be extremely high, 160,000 units per cc. It contained a small amount of trypsin, and its p_H range was from 7.5 to 8.0. The value for blood diastase was 320 units per cc., while that of the urine was 1,600 units per cc. Analysis of the stool for fat content revealed a relatively normal value of about 24 per cent.

His general condition was considered satisfactory enough to justify celiotomy for correction of the fistula, which was performed about one month after injury. Entrance into the peritoneal cavity was gained through a left upper rectus incision, with retraction of the muscle. The fistula was isolated, the dissection carried down through the gastrocolic omentum to the head of the pancreas, and the metallic foreign body which had produced the injury was located between the aorta and the duodenum. Adhesions in this area were marked, so that after due reflection upon the technical difficulties presented, the origin of the fistula was simply closed, the tract resected, closure of the abdominal wall and insertions of drains were performed in the customary

manner. However, drainage of pancreatic fluid was again noted soon after operation.

Notwithstanding this, improvement took place, and subsequently he was considered in a satisfactory condition to be evacuated to a Base Hospital in the United States. Upon admission to this hospital, a little less than four months after injury, the patient was found to be in a dehydrated, emaciated state, having lost 45 pounds in weight. The slightest exertion brought on undue dyspnea and fatigue. Anorexia was marked, and even the most tempting food failed to arouse his appetite. Lethargy and lack of interest in his environment was profound. Examination revealed little save what has been previously mentioned. A pancreatic fistula was found in a partially healed paramedian incision in the left upper quadrant. Studies of the individual blood constituents, made shortly after admission, revealed that marked deviations from normal were present: The hematocrit on initial examination was found to be 44 per cent, a relatively normal determination if it were not for the fact that this individual was markedly dehydrated, and had suffered a great change in his fluid balance. Plasma sodium was found to be 113.3 milli-equivalents in marked contrast to a normal value of 142 milli-equivalents, and emphasizes the rather serious loss of base which had occurred. Marked diminution of the plasma chlorides was also present, the plasma chloride value being 91.2 compared to the normal of 103 milli-equivalents. The total serum protein was 7.96 Gm. per cent, of which 4.92 Gm. were albumin and 3.04 Gm. were globulin. (Normal serum protein is 7.0 Gm. per liter).

Loss of pancreatic fluid varied from about 1,000 to 1,770 cc. in 24 hours. The flow was found to be quite continuous, and the predominant basic ion, sodium, was present in an amount almost approximating the quantity found in plasma itself. The bicarbonate ion was a major constituent of the cations in the fluid.

The pancreatic juice collected through this external fistula contained a considerable concentration of calcium, which would, in the absence of the fistula, have been secreted into the upper intestinal tract. This we feel is a previously unrecognized fact in calcium metabolism. Examination of a pooled specimen revealed a concentration of 2.2 mg. per cent. This figure is more significant if one recalls that the value of the diffusible calcium of the plasma is about 5.5 mg. per cent. In this particular instance 40 per cent of the total diffusible calcium of the blood plasma was being lost. Bone demineralization was not found by roentgenologic examination.

We were gradually led into making a series of physiologic observations while pursuing corrective surgical therapy. These will be reported in detail elsewhere. Obviously, the patient was not in condition at, or shortly after, the time of admission for operative treatment, and he was, therefore, prepared for eventual surgical correction of the fistula. As a matter of record the fistula closed spontaneously, and this fact is of major importance. Spontaneous closure occurred at a time when we considered the patient to have reached maximum preoperative improvement. At this time, concentration

of the various plasma electrolytes was within normal limits and the patient was in a positive nitrogen balance, having gained about 30 pounds in weight. However, to revert to the sequence of circumstances attendant upon admission, it should be noted that the fistula was producing fluid in such quantities that although spontaneous closure was considered, it was thought not quite possible. This episode, again, substantiates the fact that wounds of any sort are more prone to heal if normal physiologic and metabolic conditions are restored.

The patient was placed on a high protein, high caloric diet, but during his early days of hospitalization he had but little appetite and, at times, even refused fluids. Solutions of physiologic saline and glucose were administered intravenously when fluid intake dropped below estimated requirements. After several days of care his appetite returned. Food in relatively large amounts was easily taken, and a fairly rapid gain in weight ensued. Five weeks after admission, the plasma electrolyte pattern had assumed a relatively normal form. Evidence of a moderate degree of anemia was still present, as the red cell count was 3,500,000 per cc., and the hemoglobin content 10.2 Gm./100 cc. One thousand cubic centimeters of citrated whole blood was administered to the patient at this time. Subsequent determinations revealed that the number of erythrocytes had risen to 4,310,000 per cc., and the hemoglobin to 13.8 Gm./100 cc.

The collection of pancreatic juice from the fistula proved an exasperating problem during the early days. In addition to a desire to collect the fluid for oral administration, the surrounding skin had to be protected. A third consideration was the wish to have a method of collection which was complete, in order that some conclusions regarding volume secretion might be drawn when various drugs were administered. Several forms of apparatus, all employing a catheter and some type of suction were tried, before a satisfactory mechanical device was made. We finally settled upon the following:

The rubber bulb of an Asepto syringe was perforated at the top and a No. 14 French urethral catheter was passed completely through it (Fig. 1). The rounded tip of the catheter was cut off and a second hole made in the catheter just at the point where it passed through the bulb. Three pieces of Penrose drain, 40 cm. long and 3 cm. wide, were perforated longitudinally at their middle and placed over the projecting end of the bulb (Fig. 2). The ends of the drains were covered with adhesive and attached, as shown in Figure 3, to a second piece of adhesive tape or the familiar "Montgomery tape." A piece of roller bandage was placed between the two strips of adhesive, tightened to the necessary degree, and tied. The catheter was connected to a water suction with provision for maintaining a negative pressure of about 10 cm. of water. This not only provided for removal of the accumulated pancreatic secretion but produced a negative pressure differential which tended to seal the bulb in place. The bulb was further stabilized in its position by the elastic bands described above (Fig. 4).

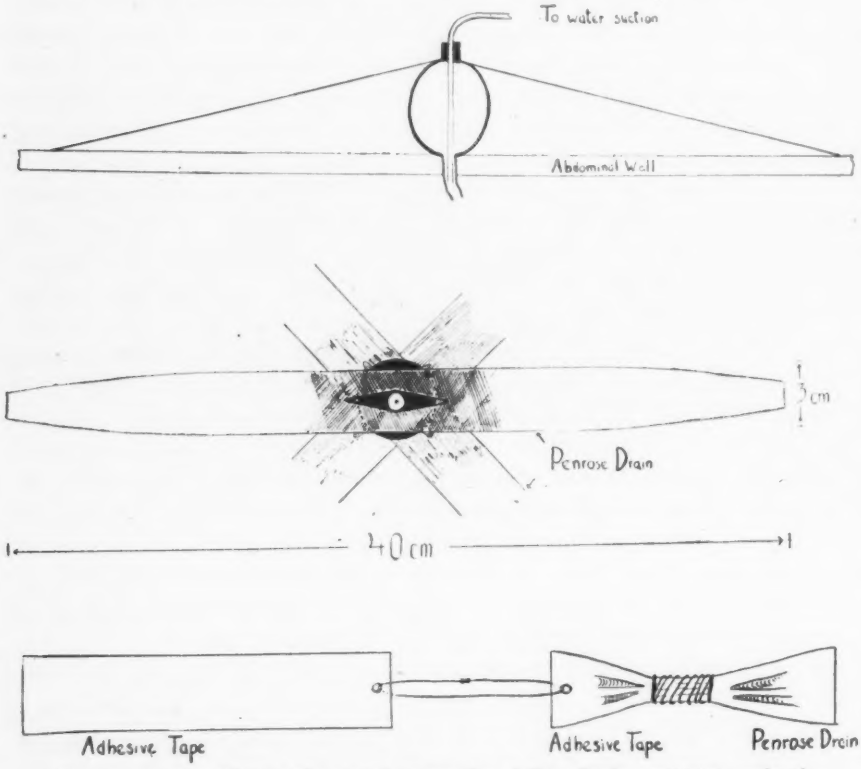
In addition a thin mixture of aluminum paste was used on the skin to advantage.

Of the many drugs that were used to influence flow through the external fistula, three will be but briefly discussed at this time:

A. Ephedrine proved an effective means of diminishing the amount of collected pancreatic juice.

B. Epinephrine acted as expected, the effect being similar to ephedrine, although much more dramatic in rapidity of onset and diminution of flow.

C. Atropine produced a marked decrease in pancreatic secretion.



FIGS. 1, 2 and 3.—Showing the general construction of the collecting apparatus employed.

Two other patients, who suffered from a pancreatic fistula, were also subjected to observation. One was a 24-year-old, white male, who sustained an abdominal injury in an automobile accident. Persistent abdominal pain was present for about three weeks and, when he was later admitted to a hospital, a large tender mass was found in the epigastrium. Celiotomy was performed on the third day of his hospital stay, and marsupialization of a pancreatic cyst was accomplished. He was eventually submitted to our care, with a history of drainage of about 500 cc. of pancreatic fluid a day, from the fistula created at operation.

Physical examination revealed normal findings, with the exception of

those in the abdomen. A fistulous opening was present in an otherwise healed left midrectus incision, and from it a colorless fluid drained.

The results of laboratory examinations at the time of admission showed: R. B. C., 5,080,000, Hb. 90.0 per cent; W. B. C. 12,300; hematocrit 46.8 per cent; sed. rate 0.60 Mm./min.; N. P. N. 24.8 mg. per cent; serum protein 6.98 Gm. per cent, serum albumin 4.50 Gm. per cent, serum globulin 2.47 Gm. per cent; chloride 96.0 m.eq/L.; carbon dioxide combining power 30.9 m. eq/L.; prothrombin time 26.0 secs.

Under hospital care, the quantity of pancreatic fluid lost through the external fistula gradually decreased and spontaneous closure occurred about five weeks after admission. It was felt, here, that a waiting period, with the patient in an optimum metabolic state, was justified to permit nonoperative closure.

FIG. 4.—Collecting apparatus applied to patient.

The idea that this period of observation might become too long was considered in the third case of this series: This patient was a 26-year-old white male, who, on arrival overseas, suffered from abdominal cramps, nausea, and vomiting. A short period of hospitalization resulted in relief, and discharge from medical care. Several episodes of similar character occurred, and after a particularly acute period of severe abdominal pain, a diagnosis of acute hemorrhagic pancreatitis was made. Celiotomy was performed, and an abscess involving the pancreas and lesser sac was encountered, incised and drained. The patient did well after operation, but a pancreatic fistula was noted shortly after surgery, which persisted to the time of admission to our hospital.

Examination revealed little except marked emaciation and weakness. A fistula from which pancreatic fluid was flowing was found in the left subcostal area.

The results of laboratory examinations showed: R. B. C. 4,280,000, Hb. 12.4 Gm.; W. B. C. 6,200; hematocrit 38.8 per cent; sed. rate 0.6 Mm./min.; N. P. N. 28.9 mg. per cent; serum protein, 6.85 Gm. per cent; sodium 140.6 m.eq/L.; chloride 103.0 m.eq/L.; carbon dioxide combining power 31.2 m.eq/L. These findings with the exception of a moderate degree of anemia and elevation of CO_2 combining power are within normal limits.

After completion of clinical and laboratory observation, decision was made to subject this individual to surgical exploration and correction of the fistula. The period of observation and preparation had been 21 days. This

decision was based upon several facts, the chief of which was that the fistula had been present for about five months. Second, the clinical laboratory studies demonstrated findings within normal limits. Third, sufficient time had been allowed for spontaneous closure to have occurred under these favorable circumstances. Fourth, there was considerable doubt in our minds as to the validity of the original diagnosis for: 1. There had been gradual rise in the left leaf of the diaphragm, as demonstrated roentgenologically. 2. A palpable mass had appeared in the upper abdomen. 3. The youth of the patient, coupled with the total absence of any previous related illness, suggested the impression of a previous error in diagnosis, as the expected appearance of acute pancreatitis in an individual of this age and build would be statistically low.

A transverse incision was made in the upper abdomen encircling the external orifice of the fistula, after which dissection to the pancreas was facilitated by following the course of the tract. The lesser sac was entered through an aperture in the gastrocolic omentum near the greater curvature of the stomach. The pancreas was found to be enlarged, firm and rubbery in consistence. There were no individual masses in the pancreas, and its texture was similar throughout the entire length. The dissection of the fistulous tract was resumed, following this exploratory palpation, and it was found that it continued into the head of the gland. Because of the small internal diameter of the fistula, and the fact that an opening into the digestive tract need not be made if transplantation were not effected, the procedure of choice seemed to be ligation of the tract as close as possible to the pancreas and subsequent excision of the fistula. This was done, and when the tract was cut across at its proximal end, a moderate amount of amorphous calcareous material was discovered and enucleated. The gastrocolic omentum was repaired by suture, and the wound closed in the usual manner.

The postoperative course was smooth for the first week. Then the patient complained of moderately severe pain in the upper abdomen, and this complaint was associated with an elevation of temperature to 102.8° F. Examination of the wound revealed the discharge of a small amount of caseous necrotic material. This persisted and heralded the recurrence of external pancreatic flow, which was noted five days after the original symptoms of abdominal pain. The amount of fluid excreted was small and gradually decreased under a dietary regimen high in fat and low in carbohydrate content. Ephedrine and sodium bicarbonate were administered orally. Complete cessation of flow was finally achieved although, subsequently, a slight flow was again noted for a short period. Complete closure was finally obtained, and at present the wound has been entirely healed for a long enough period that recurrence would seem very unlikely. The patient is entirely ambulatory, and has regained his usual weight.

This case is exemplary of those patients with fistula whose tracts do not close spontaneously when physiologic conditions apparently are at, or are near, an optimal state for healing to occur. It is felt that the calcareous

material removed at operation was a definite factor in keeping the fistula open, and that, if it were not removed, that drainage might have persisted for a much longer time. More complete recognition of the difficulties of a prolonged period of illness and the entailed economic upset, may induce the performance of operative procedure at a time when the patient has been fully prepared and a sufficient length of time allowed to pass to permit spontaneous closure.

Certain conclusions regarding the patients and their care should be emphasized:

1. Attention should be directed toward a correction of the disturbed electrolyte content of the plasma. Reemphasis is placed on the loss of large amounts of sodium and bicarbonate ions in the pancreatic juice.

2. Dehydration is effected by two agencies. Fluid is lost through the fistula, with base, and in an attempt to preserve plasma ionic equilibrium acid radicles are excreted through the kidneys, and of necessity are accompanied by water. The administration of alkaline fluids, such as sodium bicarbonate solution, is not requisite to correct this abnormal state. Physiologic saline will provide the base while the bicarbonate ion, which is produced as an end-product of cellular metabolism, is conserved in the blood stream.

3. As in other conditions in which the economy of the body is greatly affected, hematocrit determinations and erythrocyte counts are helpful in evaluating hemoconcentration only when combined with clinical observation and other laboratory data. Alone, they are of little value and may be misleading where an anemia and severe dehydration are coexistent.

4. Anemia is a striking feature of patients who are afflicted with the more severe types of fistula, as was encountered in our first case. Whole blood must be administered when necessary.

5. The lost pancreatic fluid should be collected and after being flavored, with grape juice for instance, given to the patient to drink. The fluid is ideal for replacing the lost electrolytes.

6. The best type of diet seems to be one which is high in fat and low in carbohydrate content, as flow apparently tends to be reduced in volume when patients are on this regimen. The various vitamins, especially A, iron and calcium, should be provided in adequate amounts.

7. The use of ephedrine is justified in these individuals. A definite decrease in external flow resulted from the administration of this drug.

8. An effective method for protection of the skin must be provided. A combination of the mechanical device which was described earlier and aluminum paint has been found to be quite effective in achieving this end.

9. The surgical procedure of choice must be dictated by the individual circumstances. It is our particular feeling that a conservative course, with attention to the many aspects of metabolism, will result in spontaneous closure of the fistula in the majority of cases. If, after a sufficient period with the patient in an optimum condition, the fistula has not closed, surgical intervention is justified.

PRIMARY GASTRIC RESECTION FOR PERFORATED GASTRODUODENAL ULCERS

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EVERY WELL PREPARED SURGEON has a routine method for performing a stated operation, but he does not restrict himself to a routine operation for a given lesion. Thus, he is prepared to vary his operation for the removal of a diseased gallbladder or an ulcer of the stomach, for instance, according to the exigencies of the case.

However, in this country a review of the literature shows that this has not been the case in the surgical treatment of acute perforations of gastroduodenal ulcers. The treatment for this has been routine; namely, suture of the perforation and closure of the abdomen with or without drainage. Some few surgeons once advocated occasional gastro-enterostomy to relieve constriction resulting from closure. But as Sallick wrote in 1936: "In this country gastric resection for acute perforation is rarely advised."

The reasons for simple closure as often put forth by conservative surgeons and expressed by Graham are: "The surgeon's sole responsibility is to save the patient. At this time he does not have the responsibility of curing the ulcer. Any operative procedure directed toward the cure of ulcer is unsound, meddlesome, and adds greatly to the mortality as well as to the morbidity."

He operated upon 36 consecutive cases of perforation without a death, performing closure only. Sixteen of these required subsequent operations. Sallick said that 64 per cent of his cases were not relieved by simple closure. Parker's figures come exactly between these two; 50 per cent of his patients followed (in some cases for five years) did not remain well.

The first gastric resection for perforated gastroduodenal ulcer was performed by Haberer in 1929 (B. Neiss). Four years later Amos Graves wrote: "The common presence of multiple peptic ulcers in German or Central European patients with perforated peptic ulcer has encouraged German and Austrian surgeons to resect the stomach primarily—such surgery not only cures the patient but is attended by a low mortality rate." He adds almost apologetically: "The study—is presented for its interest and not with the intention of encouraging the institution of surgical measures which seems too radical for the successful handling of the usual type of perforated peptic ulcer encountered in North America."

However, after presenting the good results of 144 cases from Schmieden's Clinic and 4,258 additional, he was compelled to this conclusion: "Resections in good-risk Central European cases is probably justified because"—

1. The ulcers are multiple in 30 per cent of perforations.
2. Gastritis is usually present.

3. The pathologic condition cannot be evaluated by inspection and palpation alone.
4. Resections there are performed in 40–75 minutes.
5. Mortality is not over 5 per cent.
6. Technically easier than in elective cases of peptic ulcer.
7. Simple methods do not always cure and are frequently followed by recurrences.
8. Resection later, in failures, carries a high mortality.

A few comments on the above points favoring resection are in order. The first, of course, is the reason why some patients are operated upon for a perforated ulcer a second and third time when only simple closure is effected. Lang reported five deaths due to a second perforation that had been overlooked and two deaths from late postoperative perforation of another ulcer. Most surgeons now admit the second point in all gastric ulcers. Third, it is true that the perforation may be through a carcinomatous ulcer. As for the time required for primary resection, Serge Yudin ("Judine" in French Journals) reported in 1933 that of 212 cases of perforated gastroduodenal ulcers in his clinic, 168 resections were performed with a mortality of 6 per cent. Of these he operated upon 60 per cent. The other 40 per cent were operated upon by his assistants "some even by young interns." The usual time required in my cases was close to two hours—and still no deaths resulted. Time is not so important as the anesthesia and postoperative care. Reasons six, seven, and eight given above are admitted by the conservative surgeon.

The list of European surgeons who prefer primary resection for perforated gastroduodenal ulcer is a long one. Of course, they select their cases, and that shows that they are not restricting themselves to a routine procedure for this lesion. The same factors influence the mortality rate for resection as for simple suture. Yudin states that the number of hours elapsing after perforation is not the only deciding factor. He would resect in the case of a young person after 48 hours, whereas he would not resect in the case of an old patient even if the perforation were only two hours old. He selects those under 45 years of age for resections.

Friedman, Dreuter, Kuechel, and Richard favor radical operation in perforations up to six hours and not after nine hours. Some surgeons are guided by the degree and extent of the peritonitis, and some by the general condition of the patient. Yudin stresses the virulence of the infection. Hans Neuffer concluded that a case resected within the first four hours has the same chances as one resected for chronic ulcer. His time limit for resection is ten hours and the age limit fifty. He emphasizes the need for selection. It would seem to the author that the virulence of the infection may be extremely important because of the loss of one patient, age 45, in less than 24 hours after simple closure, nine hours after perforation. Niess, from Schmeiden's clinic, found no relation between mortality and duration of symptoms. His figures were:

Less than 6 hours	40 patients	3 deaths
6 to 12 hours	15 patients	1 death
12 to 24 hours	5 patients	0 deaths

The statistics from clinics where simple closure of a perforation of a gastroduodenal ulcer is done as a routine show higher mortality figures for comparable cases. Therefore, let us examine the age-group that might be chosen for resection. DeBakey's review showed that the mortality of the cases sutured in the fourth decade was 18.9 per cent; in the fifth it was 28 per cent. Likewise, the deaths resulting in those perforated for only six hours totaled 10.5 per cent; seven to twelve hours totaled 21.4 per cent.

Graves' collected cases showed 5,589 simple closures with 1,450 deaths, or 25.9 per cent, and for 2,392 gastrectomies, 321 deaths, or 13.4 per cent. Of course, the latter were selected cases, but it is my thesis that gastrectomy by selection does not jeopardize the patient's life.

If, therefore, it can be shown that primary resection is as feasible in America as in Europe without jeopardizing the patient's chance for recovery and at the same time cures him of his ulcer, the dictum of the conservative surgeon may be forgotten. As for history, symptoms, signs, and laboratory findings in this series, they conform to those of the large series.

Continuous spinal anesthesia with novocaine is the anesthetic of choice today. Postoperative treatment was the same as for a routine gastric resection. Sulfanilamide and sulfathiazole, three to four grams of each, are left in the abdomen. Wangensteen's tube, with suction, is left in as long as necessary. Intravenous glucose, amino-acids, vitamins and transfusion are administered. Water by mouth is usually given after 48 hours. Usually the wound is closed without drainage.

In the author's series there was one case of postoperative pneumonia and two of wound dehiscence, one of which was followed by a ventral hernia which has since been repaired.

The present series consist of 12 consecutive cases, all males, from March 9, 1939, to March 11, 1943. It includes eight resections and four sutures, and starts with a resection. Up to this time I had followed the traditional dictum of being content with primary suture only, with one exception when I had added a gastro-enterostomy.

It so happened that the first case of the series was a man age 60, an age commonly considered too old for primary resection. But this patient had had a perforated peptic ulcer sutured 14 years previously; had been on ulcer treatment most of the time since; and had only recently left another hospital where his doctor had discharged him as "cured" after the "drip" treatment. He had been sent to Mt. Sinai Hospital for roentgenologic examination of his stomach by another doctor and had arrived too late. He was put to bed and given a test meal, which showed a free acid of 48–80 and a total acidity of 35–120. That night while in bed in the hospital he was seized with sudden severe upper abdominal pain and vomited. Examination

			Symptoms recurred one year later and persisted. Rupture occurred in hospital	N_2O-O-E	Polya resection—2 hours, 15 minutes	Much free fluid. Opening 1.5 cm. in diameter. Anterior wall prepyloric. Chronic peptic ulcer 13 Mm. Chronic subacute gastritis with marked scarring. Chronic polypoid gastritis. Regional peritonitis	1 Transfusion Uneventful	Well
	2	30	4/1–4/15/39	Indigestion 3 months. Restricted diet. Severe abdominal pain and nausea. No vomiting. Six hours before admission doctor gave dilaudid.	N_2O-O-E	Polya resection—2 hours	Anterior stomach wall. Perforation 3 Mm. in diameter. Peptic ulcer. Chronic hypertrophic gastritis. Regional peritonitis	Uneventful	Well
	3	43	12/5/40–1/21/41	2½-3 weeks ago epigastric cramps. Diarrhea 3-4 hours after meals. Sudden severe cramp tonight while eating	N_2O-O-E	Polya resection—2 hours, 15 minutes	Duodenal perforation. Chronic and subacute duodenitis. Chronic polypoid gastritis. Regional organizing and acute fibrinopurulent peritonitis	Postoperative pneumonia	Well
	4	37	1/4–1/31/41	Indigestion 6 years and ulcer treatment. X-ray negative. Pain in abdomen in afternoon. Consulted doctor. Sudden severe pain in abdomen and right shoulder 2 hours previous to admission	N_2O-O-E	Polya resection—2½ hours. Sulfathiazole	Perforation 5 Mm. in diameter. Peptic ulcer. Subacute and acute gastritis and local peritonitis	Uneventful	Well
63	5	45	7/17–7/18/41	Indigestion one year. Seven hours ruptured	Novocaine. Spinal 75 mg. Novocaine	Sutured. Sulfanilamide	2 ulcers. 1 perforated 6 Mm. in diameter. Prepyloric. Generalized peritonitis. Streptococcus and *B. coli*. Peritoneal cultures	Died less than 24 hours after admission	Died
	6	31	8/19–9/12/41	Onset 8/17/41 with pain in upper abdomen. Midnight 8/18/41 pains grew worse and involved whole abdomen. ? Hrs. ruptured?	N_2O-O-E	Polya resection. Sulfathiazole	Perforation 5 Mm. anterior surface prepyloric ulcer 2 cm. 1 polypus. Chronic subacute and acute gastritis. Regional peritonitis	Uneventful	Well
	7	65	12/18–12/23/41	Gastro-intestinal complaint 10 years. General abdominal pain since yesterday	N_2O-O-E	Suture of perforated ulcer. Sulfanilamide	Blood pressure 80/60. Rose 12/19 to 110/70. Gastric ulcer, anterior surface	Blood chemistry normal throughout	Died 5 days
	8	39	4/6–4/24/42	General abdominal pain last night. Indigestion in past. Pain recurred at work with tenderness	Continuous spinal Novocaine	Polya resection	Chronic and subacute gastritis. Chronic and acute peptic ulcer 3 cm. in diameter. Perforation 7 Mm. Regional peritonitis	Blood chemistry normal. 2/18 T. 104 4/14 T. 98	Well
	9	22	5/11–5/22/42	Several months abdominal pain after meals. Severe pain shortly before admission	Continuous spinal	Polya resection	Prepyloric ulcer anterior surface	Uneventful	Well
	10	52	11/22/42–1/8/43	Hematemesis 1 month previous. Acute abdominal pain 12 hours	Continuous spinal. Novocaine	Suture only. Sulfathiazole		Wound rupture and resutured. 12th rib resected for drainage of subphrenic abscess. Had delirium tremens	Well
	11	38	3/11–3/17/43	History of stomach trouble. 5 hours sudden pain. Vomited once.	Continuous spinal	Suture. No sulfathiazole	Prepyloric ulcer. Marked peritonitis and cirrhosis liver, confirmed by biopsy	Icterus index 41 3/16 index 121	Died 5 days
	12	25	3/11–4/8/43	Abdominal distress 2 weeks. Tarry stool 1 week ago	Continuous spinal	Polya resection. Sulfathiazole	Duodenal ulcer. Chronic and acute hypertrophic gastritis	Temperature elevation 16th day. Normal 22nd day. Discharged 28th day	Well

revealed the usual generalized board-like rigidity and tenderness most marked in the upper abdomen. He was operated upon less than two hours later. Much free fluid was found in the abdomen and a perforation about 8 Mm. in diameter in the anterior wall of the stomach in the prepyloric region. A typical Pólya resection was performed. The pathologist reported a chronic peptic ulcer 13 Mm. in diameter, chronic and subacute gastritis with marked scarring, chronic polypoid gastritis, and regional peritonitis. Nitrous oxide, oxygen and ether was the anesthetic. The operation required two hours. The patient was given one transfusion postoperatively. Recovery was uneventful, and the patient is well and happy today and not restricting his diet.

Twenty-three days later, April 1, 1939, I had occasion to operate upon my next case of perforated peptic ulcer. This time the patient was a strong man, age 30, who had ruptured about six hours previously. It was only logical to conclude that if the old man of 60 did well I had a better chance with this young man of 30, although the perforation was older. His doctor telephoned me his patient had severe abdominal pain and that he had given him dilaudid twice without relief. To further questions he said the patient had had indigestion for three months and had been on a restricted diet. His pain came on suddenly. I told the doctor to send the patient into the hospital at once because it sounded like a perforated peptic ulcer, and I notified the hospital to prepare the operating room. The patient was operated upon within one hour after admission. Again, a Polya resection was performed, with excellent result. He left the hospital well on April 15, a sojourn of two weeks.

After this auspicious start I no longer felt bound by conventions. Table I shows the sequence and gives the essential information. Inasmuch as there were no deaths in the gastrectomy cases no criticism can be made that the results might have been better with suture alone. No one's life was jeopardized or sacrificed. All cases were cured both of their perforations and their ulcers. Their convalescence was not so long nor so limited in diet as is usually necessary for the cure of ulcer. The average hospital stay was 23 days, the shortest was 11 and the longest (due to a postoperative pneumonia) was 47 days.

On the other hand, gastric resections were not performed as routine, as witness the four cases of suture only. In fact, I believe that my judgment was correct in selecting these cases for suture because three of them died and if resected, gastrectomy would have been blamed. As it happened none fitted the required conditions for gastric resection. These four show that it is not just one element alone which is the deciding factor in all cases. Case 5 was 45 years old, and had perforated at least seven hours before admission to the hospital. He was adjudged toxic, had two ulcers, one perforated; and had streptococcus and *B. coli* in culture from the peritoneum. He died in less than 24 hours. The second, aged 65, had perforated over 12 hours. The third fatal case was only 38 years old, but had a large cirrhotic liver, proved

by biopsy. He developed delirium tremens and jaundice postoperatively, and died in five days. He was operated upon in the early hours of the morning, immediately before Case 12, a Negro, age 25, the last resection case of the series. The fourth suture case was age 52; an alcoholic who also developed delirium tremens; then a wound dehiscence which was resutured; and, finally, a large subphrenic abscess which was drained. He recovered. I am sure not even the European surgeons would have resected anyone of these four.

Therefore, I think it can safely be said that in selected cases primary resection for perforated gastroduodenal ulcers offers the patient a cure of his disease; it saves him further ulcer treatment and second operation. It removes the danger of another perforation, and it does not increase the operative mortality above that of simple suture. It does not add to his morbidity. He is soon on an unrestricted diet. It should supersede routine suture in younger patients in good condition.

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ATRESIA OF SMALL INTESTINE*

TWO CASE REPORTS; ONE MULTIPLE ATRESIA, WITH SURVIVAL

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ATRESIA OF THE SMALL INTESTINE is a relatively rare condition, occurring once in every 20,000 births, according to Webb and Wangensteen.[1] Recoveries following surgical intervention are still more infrequent. Fochens,[2] in 1910, reported the first successful case, and Webb and Wangensteen,[1] in 1931, were able to collect only nine instances of survival from the literature. Ladd,[3] in 1933, collected 14 successful surgical cases.

In 1941, Ladd and Gross[4] reported seven recoveries in 52 personal cases treated surgically at the Children's Hospital in Boston. Cole, in discussing Ladd's[3] paper in 1933, recorded seven cases of atresia of the intestine at the St. Louis Children's Hospital. Four of these were treated by anastomosis and three by ileostomy, but none survived.

Atresia results from an arrest in development in the second or third month of fetal life. This is a failure of recanalization of the intestinal tract following the obliteration of the original lumen between the fifth and tenth week by epithelial concrescences.

The sites of atresia in Ladd's[4] 52 cases were: In the duodenum in 5; jejunum in 6; ileum in 34; ileocecal valve in 2; colon in 2; and multiple in 3. Our successful case was multiple atresia of the jejunum, and the other occurred in the midportion of the small intestine or beginning third of the ileum. As far as we know, this is the second case of survival of multiple atresia of the small bowel. The first case was reported in November, 1943, by Duncan, *et al.*[5]

Attention is directed to the condition by persistent vomiting and lack of normal meconium. Ladd[4] stressed the fact that the examination of the stools may be of aid in determining the presence of a complete occlusion. Normal meconium contains keratinized epithelium from vernix caseosa in swallowed amniotic fluid. This epithelium is easy to recognize (Farber's test) and obviously is absent when complete obstruction exists.

Distention may or may not be a factor. In atresia of the duodenum or high jejunum, it is absent or negligible.

The most valuable laboratory test is a plain film of the abdomen. This shows distended loops of bowel and step-ladder levels in the erect posture. Some additional information is obtained in having a roentgenogram taken in the head-down position. Barium by mouth or rectum gives little further

* Read before the Philadelphia Academy of Surgery, April 3, 1944.

diagnostic aid. Furthermore, it is not without danger, because the barium might clog the narrow lumen of the distal loops following anastomosis. A greater danger is that of bronchopneumonia following aspiration of the vomited barium. Autopsies revealed bronchopneumonia in a high percentage of the unsuccessful cases.

The differential diagnosis is not difficult. The two conditions which most nearly simulate it are atresia of the esophagus and imperforate anus. The inability to pass a stomach tube will identify the first, and simple inspection the latter. Pyloric stenosis, as a rule, occurs later in life. Obstruction due to malrotation is not usually complete, and furthermore, celiotomy is indicated in both conditions; so little harm results from mistaking one for the other.

The possibility of the aspiration of gastric contents necessitates gastric lavage as a preoperative measure, or one might consider inserting an inlying gastric tube. Naturally, preoperative treatment includes liberal administration of parenteral fluids.

With this brief résumé of the condition, we wish to report the following two cases. For those especially interested, we recommend the articles by Webb and Wangensteen,[1] and Ladd,[3] and the chapter on congenital atresia of the intestine and colon in Ladd and Gross' "Abdominal Surgery of Infancy and Childhood."[4]

CASE REPORTS

Case 1.—P. H. is a colored male child whose birth was in every way normal. One hour following all feedings he vomited, and at the end of 36 hours had been unable to retain anything. He never passed meconium but had a stool which appeared to be an intestinal cast containing no lumen. The vomitus was bile-stained and projectile in type. Repeated enemas were ineffectual for fecal matter nor did they relieve the distention, which was prominent. Visible peristalsis was noted crossing the abdomen and, on auscultation, high-pitched tinkles were heard. Roentgenologic studies revealed an obstruction in the upper portion of the small bowel with marked distention of the stomach and duodenum.

After preparation with repeated hypodermoclyses of saline and glucose solution, plasma intravenously and gastric aspiration, the child was operated upon at about the 64th hour of life, February 15, 1943. Preoperatively, he was given atropine sulfate, gr. $\frac{1}{1000}$. Open-drop ether anesthesia was used. The abdomen was opened through a left rectus incision. At a point approximately ten inches from the ligament of Treitz, the obstruction was encountered in the form of an atresia. Distal to this were found three sausage-shaped loops of bowel, blind at both ends and measuring 2.5, 2 and 6 cm. in length. Each segment had its own solitary blood supply. The distal loop appeared to be connected with the ileum, and this was simply ligated with one piece of No. 000 catgut. An open side-to-side isoperistaltic anastomosis was carried out between this markedly distended jejunum and the completely collapsed ileum, using No. 00000 chromic catgut throughout. The abdomen was closed in layers without drainage.

Postoperatively, the patient received frequent hypodermoclyses of glucose and saline solution. Fifty cubic centimeters of plasma were given intravenously for two days. Twelve hours following operation, the temperature rose to 107° F. but fell to normal on the following day. A small abscess at the site of a retention suture was probably

A B C

FIG. 1.—(A) Plain film of Case 1 (P. H.); (B) erect position; and (C) head-down position.

responsible for spikes of temperature up to 102°–103° F. during the first five days. Following this, it remained normal. Because of the rather marked jaundice, vitamin K was given parenterally as a prophylactic measure for hemorrhage. On the third postoperative day, the baby was started on breast milk, one-half ounce every two hours. Two bowel movements occurred on the fourth postoperative day. After this, improvement was rapid. He was discharged from the hospital on his 28th day of life in good condition.

FIG. 2.—Drawing of findings at time of operation in Case 1 (P. H.).

On March 25, 1944, the baby weighed 14 pounds 10 ounces, and although he could not sit up alone, generally, he seemed fairly alert. He has occasional episodes of vomiting, and a gastro-intestinal roentgenogram showed a certain amount of hypomotility of the small intestine with some pooling of barium at what appeared to be the site of the anastomosis. However, this had all passed into the colon at the end of 24 hours. No trace of the barium could be seen on a plain film six days later.

Case 2.—F. W. was a colored male child whose birth was normal. On the second day of life, his abdomen became distended, but vomiting did not occur. Peristalsis was hypo-active. Digital examination revealed no obstruction low in the rectum. An enema was effectual for only a small amount of mucinous material. Roentgenologic

C

B

A

FIG. 3.—(A) Plain film of Case 2 (F. W.); (B) erect position (note air under diaphragm); and (C) head-down position.

study revealed marked distention of the small bowel down as far as the ileum. Air was noted beneath both diaphragms, suggesting a probable perforation.

Preoperative preparation consisted of saline and glucose solution by hypodermoclysis, vitamin K parenterally and gastric aspiration. Under open-drop ether anesthesia, the abdomen was opened through a left rectus incision. A moderate amount of faintly-cloudy fluid was encountered, and air was noted to escape as the peritoneum was opened. An atresia was found in the midportion of the small bowel. The proximal loop was greatly distended and parts of it covered with a yellowish fibrinous exudate, but no site of perforation could be detected. The proximal and distal loops were approximated and a side-to-side isoperistaltic open anastomosis was done, using an inner layer of No. 00000 chromic catgut and an outer layer of arterial silk. The abdomen was closed in layers without drainage.

Postoperatively, jaundice became prominent. Despite the administration of parenteral fluids, one transfusion, vitamins K and C and repeated gastric aspirations, the temperature gradually rose to 104° F., and the patient died 46 hours later. Autopsy revealed death to be due to bronchopneumonia and possibly shock. There was no evidence of peritonitis.

DISCUSSION.—As in intestinal obstruction due to any cause, early recognition of the condition lowers mortality. Therefore, the result of surgery depends primarily upon the astuteness with which the pediatricians diagnose the case and the promptness with which it is brought to surgery.

Anesthesia.—In our two cases, the suggestion of Ladd and Gross[4] in using open-drop ether was followed. Local anesthesia might be considered, but the anastomosis is of such a nature as almost to demand a quiet operative field.

Operative Technic.—One of our main reasons for presenting these two cases is to emphasize the need of performing a primary anastomosis. On opening the peritoneum, the discrepancy in size between the collapsed loops of bowel and distended bowel is so great that anastomosis seems to be a technical impossibility. Only the insistence of Ladd and Gross[4] that this is the only procedure that offers any hope for survival made us attempt it in our first case.

Ileostomies have probably been the most commonly employed procedure, but the results have been almost invariably fatal. The only two successful cases reported[3, 6] in which this technic was employed were done for atresia in the terminal ileum. The higher in the small intestine the atresia is, the greater is the electrolytic imbalance resulting from the loss of intestinal contents through an enterostomy. The primary ileostomies probably did very little to facilitate secondary anastomoses, one of which was done within two months and the other 30 days following the original procedures.

The distal lumen is so narrow that Wangensteen[2] has suggested dilating it by injecting it with saline. Ladd and Gross[4] have used a small catheter for dilatation. We used neither of these suggestions, but in our successful case we did not put in a second anterior layer for fear of so inverting the mucosa as to occlude the lumen.

Fine suture material is essential. In the first case, No. 00000 catgut was used throughout. The ideal suture material is arterial silk for the serosal layer and No. 00000 catgut on a swedged needle for the mucosal layer.

Our second case, in retrospect, might have had a better chance of survival had our intravenous administration of blood or plasma been more vigorous. These are long procedures, and infants are subject to shock just as adults are. We are inclined to neglect this point, possibly because intravenous therapy is difficult in the newborn. Anemia should be corrected by the administration of blood in the amount of 5–8 cc. per pound of body weight. It is well to keep in mind that the loss of 30 cc. of blood in an infant is equal to about 500 cc. in an adult. Body heat can be conserved by placing a hot water bottle under the child's back during the procedure.

The transient hypoprothrombinemia of the newborn leading to hemorrhagic tendencies is now common knowledge. Disorders of the gastrointestinal tract, such as pyloric stenosis or obstruction due to atresia or malrotation, are particularly prone to develop hypoprothrombinemia.[7] One of the cases of atresia reported by Webb and Wangensteen[1] died of postoperative hemorrhage from the wound and into the peritoneal cavity. This not infrequent fatal postoperative complication can best be treated by the specific prophylactic administration of vitamin K preoperatively, the dose being 1–2 mg. of one of its synthetic forms. An increase in the blood prothrombin can usually be detected within two to six hours.[7]

The question of sulfonamides arises. There is probably very little indication for their intraperitoneal use. Though no bacterial studies confirm the following statement, one would naturally assume that the intestinal contents in the newborn have a much lower bacterial count than later in life. Peritonitis was not a frequent cause of death in reported cases. Bronchopneumonia was the most common finding at autopsy.

SUMMARY

Two cases of intestinal atresia treated by primary anastomosis have been reported, one being the second successfully treated case of multiple atresia.

The unsuccessful case was technically satisfactory, and more vigorous postoperative care might have prevented a mortality.

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CAUDA EQUINA COMPRESSION SYNDROME WITH HERNIATED NUCLEUS PULPOSUS

A REPORT OF EIGHT CASES

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MUCH HAS BEEN WRITTEN on the subject of herniation of the nucleus pulposus in its more common form but little has been described concerning the clinical manifestations of extensive protrusions. We have had occasion, recently, to observe a number of instances of this type in which the protrusions were so extensive as to produce complete, or nearly complete, subarachnoid block with cauda equina compression. The resultant anamnesis so closely simulates cauda equina tumors that most of the early cases were explored for suspected neoplasms, and it was not until the condition had been encountered on several occasions that the possibility of herniated nucleus pulposus could be anticipated. In our experience, indeed, cauda equina compression occurs much more frequently due to herniated nucleus pulposus than to tumor. For this reason, this series of cases is reviewed to evaluate the presenting clinical manifestations, means of diagnosis, operative findings, and the sequelae encountered. These patients have all been observed and treated at the Strong Memorial and Rochester Municipal Hospitals during the past 18 months.

CASE REPORTS

Case 1.—F. S., S. M. H. No. 199505: The patient was a 28-year-old housewife who, 15 months prior to admission, following a normal pregnancy and delivery, developed low back pain on the left side. She was treated for "scoliosis" with a plaster jacket which she wore for three months. The pain disappeared almost entirely until three days prior to admission when, while stooping over, she felt her back "snap." There was immediate pain in the back and down the legs, which increased in severity until admission. The day before entry, numbness of the right leg, left leg, left foot, back of left thigh, vulva, and perineum developed in that order. There was some twitching of the muscles of the buttocks. For 24 hours the patient had been unable to void spontaneously, being incontinent of small amounts of urine occasionally. There had been no bowel movements for two days. The patient was bedridden because of the pain. The past history was negative except for rheumatic fever at age 22.

Physical Examination: This revealed a moderately obese, bedridden young woman in some pain. The general physical and neurologic examinations were not remarkable except for the following positive findings: There was a coarse nystagmus on extremes of lateral gaze. The bladder was palpable nearly to the umbilicus. There was tenderness over the fifth lumbar spine. There was no abnormal alignment of the spine with the patient recumbent, and it was not possible to have her stand. There was a marked weakness of both legs varying from minimal changes in the upper leg muscles to almost

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Our second case, in retrospect, might have had a better chance of survival had our intravenous administration of blood or plasma been more vigorous. These are long procedures, and infants are subject to shock just as adults are. We are inclined to neglect this point, possibly because intravenous therapy is difficult in the newborn. Anemia should be corrected by the administration of blood in the amount of 5–8 cc. per pound of body weight. It is well to keep in mind that the loss of 30 cc. of blood in an infant is equal to about 500 cc. in an adult. Body heat can be conserved by placing a hot water bottle under the child's back during the procedure.

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MUCH HAS BEEN WRITTEN on the subject of herniation of the nucleus pulposus in its more common form but little has been described concerning the clinical manifestations of extensive protrusions. We have had occasion, recently, to observe a number of instances of this type in which the protrusions were so extensive as to produce complete, or nearly complete, subarachnoid block with cauda equina compression. The resultant anamnesis so closely simulates cauda equina tumors that most of the early cases were explored for suspected neoplasms, and it was not until the condition had been encountered on several occasions that the possibility of herniated nucleus pulposus could be anticipated. In our experience, indeed, cauda equina compression occurs much more frequently due to herniated nucleus pulposus than to tumor. For this reason, this series of cases is reviewed to evaluate the presenting clinical manifestations, means of diagnosis, operative findings, and the sequelae encountered. These patients have all been observed and treated at the Strong Memorial and Rochester Municipal Hospitals during the past 18 months.

CASE REPORTS

Case 1.—F. S., S. M. H. No. 199505: The patient was a 28-year-old housewife who, 15 months prior to admission, following a normal pregnancy and delivery, developed low back pain on the left side. She was treated for "scoliosis" with a plaster jacket which she wore for three months. The pain disappeared almost entirely until three days prior to admission when, while stooping over, she felt her back "snap." There was immediate pain in the back and down the legs, which increased in severity until admission. The day before entry, numbness of the right leg, left leg, left foot, back of left thigh, vulva, and perineum developed in that order. There was some twitching of the muscles of the buttocks. For 24 hours the patient had been unable to void spontaneously, being incontinent of small amounts of urine occasionally. There had been no bowel movements for two days. The patient was bedridden because of the pain. The past history was negative except for rheumatic fever at age 22.

Physical Examination: This revealed a moderately obese, bedridden young woman in some pain. The general physical and neurologic examinations were not remarkable except for the following positive findings: There was a coarse nystagmus on extremes of lateral gaze. The bladder was palpable nearly to the umbilicus. There was tenderness over the fifth lumbar spine. There was no abnormal alignment of the spine with the patient recumbent, and it was not possible to have her stand. There was a marked weakness of both legs varying from minimal changes in the upper leg muscles to almost

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complete paralysis of the anterior tibial group on the left side. Anesthesia was present in the saddle area, dorsum of both feet, toes, and the sole of the right foot. Hypesthesia was present over the left sole and lateral and posterior aspects of the left leg. Position sense was impaired on the left. Both ankle jerks were absent, but the knee jerks were equal and brisk.

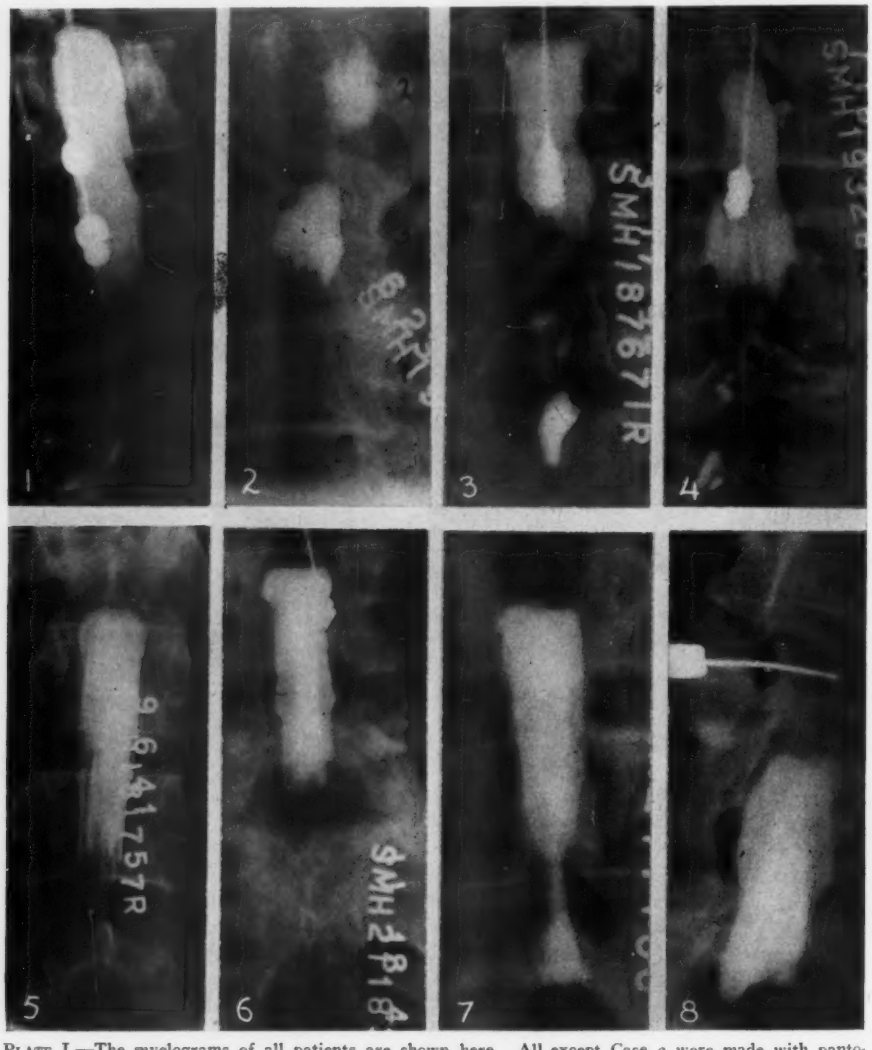

PLATE I.—The myelograms of all patients are shown here. All except Case 2 were made with pantopaque. All were taken with the patient on the fluoroscope table in a nearly erect position.

Laboratory Data: Red blood count of 4.7 million, hemoglobin of 15 Gm.; white blood count of 13,500, with a normal differential. The serology was negative. The urine contained 3–5 white cells per high power field; and *Escherichia coli* was cultured. Lumbar puncture between the third and fourth lumbar vertebrae demonstrated normal manometrics. The fluid showed a negative serology, and a protein content of 110 mg. per cent.

Roentgenograms of the lumbar spine showed narrowing of the fourth lumbar body, and the third, fourth, and fifth lumbar interspaces on the left. Pantopaque myelography demonstrated a complete subarachnoid block at the third lumbar interspace (PLATE I, Fig. 1).

The patient was given sulfadiazine orally and placed on Monroe catheter drainage. On the 18th hospital day, a laminectomy was performed exposing the third lumbar interspace but no defect was seen. The dura was opened, revealing extensive arachnoid thickening with gross matting of the nerve roots of the cauda equina. Exploration with a catheter revealed an obstruction at the fourth interspace, which was subsequently explored, and a large herniated nucleus pulposus removed. The obstruction at L-3 by myelography was felt to be due to the arachnoid adhesions seen on opening the dura.

Postoperatively, the patient was free of pain. She gradually regained control of her bladder and was able to void spontaneously 15 days after operation. When last seen, eight months after operation, she had a mild residual vulvar anesthesia, but normal sphincter control. She was able to walk with the aid of a cane, there being some residual foot drop on the left.

Case 2.—M. D., S. M. H. No. 192500: The patient was a 62-year-old railroad worker who, except for 40-pound weight loss during the preceding two years, was in excellent health until three weeks prior to admission, at which time he awoke with a severe pain in his back radiating down the left leg. This pain persisted and was followed by weakness. Ten days prior to admission, numbness of the lateral aspect of the left leg was noted, and five days later, he was unable to walk because of the weakness and pain. For about a week before entry, there was some nocturia. The pain was aggravated by coughing. Twitching of the muscles of the legs and arms was reported for approximately two months. He had progressive difficulty in voiding but was still continent at the time of operation.

Physical Examination.—This revealed a well-developed elderly man showing some evidence of weight loss. General and neurologic examinations were not remarkable except for the following positive findings: The rectal sphincter was moderately relaxed. There was bilateral weakness of all muscle groups of the legs, more pronounced on the right side and in the peroneal regions. Occasional localized twitchings were seen in the upper and lower extremities. There was sensory loss as high as the first lumbar dermatome on the right and the third lumbar dermatome on the left. Little change was noted in the sensation of the legs but the patient was not able to cooperate well enough for a very exact sensory examination. There was bilateral loss of position and vibratory sense. The left knee jerk was diminished. The right knee jerk and both ankle jerks were absent.

Laboratory Data: Blood studies were normal except for a blood sugar of 200 mg. per cent. Uranalysis revealed a glycosuria. Serology was negative. Lumbar puncture at the fourth lumbar interspace showed a complete block, with xanthochromic fluid having a protein content of 630 mg. per cent. Roentgenograms of the lumbar spine demonstrated a list, with convexity to the right, narrowing of the second lumbar intervertebral space, and hypertrophic changes.

Lipiodol was introduced by cisternal puncture. A complete block was visualized at the third lumbar intervertebral space (PLATE I, Fig. 2). The protein content of the cerebrospinal fluid withdrawn at this time was 25 mg. per cent.

The diabetes was controlled with 20 units of protamine-zinc and 10 units of regular insulin daily. On the tenth hospital day, the patient's spinal canal was explored for tumor of the cauda equina. The third and fourth lumbar laminae were removed, exposing a large herniated nucleus pulposus, which was apparent even on the dorsal surface of the dura (Fig. 1). This was removed (PLATE II, Fig. 1) and the dura opened, revealing matting and injection of the roots of the cauda equina together with a thickened milky-appearing arachnoid. A spinal fusion was carried out.

The postoperative course was complicated by some fecal incontinence, but motor power returned gradually. Bladder and bowel function were normal one to two months after operation. Seventeen months after operation, the patient was asymptomatic, and employed as a laborer. Both ankle jerks were diminished but there was no localized weakness or sensory abnormality.

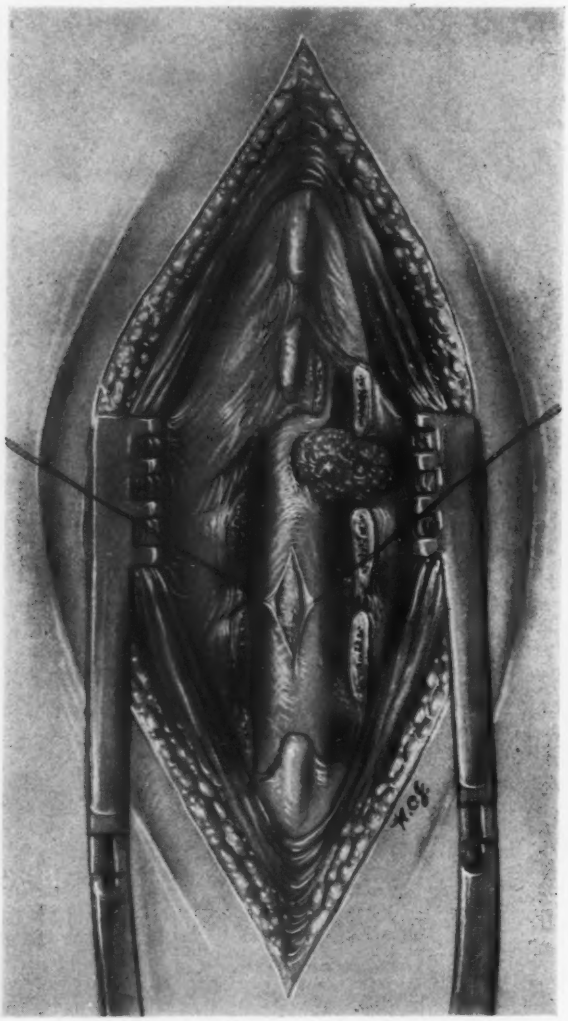

FIG. 1.—A diagrammatic representation of the pathology encountered in Case 2. A cauda equina tumor was anticipated, which accounts for the wide exposure. The extent of the protrusion of the nucleus pulposus is demonstrated at the third lumbar interspace.

Case 3.—A. T., S. M. H. No. 187681: The patient was a 37-year-old cabinetmaker who, for 15 years, had had "lumbago," characterized by low back pain of an intermittent nature coming every three to four months and lasting two or three days at a time. Six months prior to admission, the back pain became more severe, radiating down the back of both legs (the left more than the right). Pain progressed until two

months before admission, when it was knife-like in nature. It was aggravated by coughing and sneezing. No relief was obtained from chiropractic treatments or arch supports. Some frequency of urination and a sensation of fullness of the bladder was noted during this period, as was increasing constipation. Past history was remarkable only in that patient was reported to have had "tuberculosis of the hip" at the age of seven.

Physical Examination.—This revealed the following positive findings: The patient was a muscular man who appeared to be in considerable pain. Movements of the back were limited in all directions although there was no definite list. Straight leg-raising was limited to 30° on the right and 20° on the left. There was measurable atrophy of the left thigh and calf. The Lasègue's sign was positive bilaterally. There was a patchy hypesthesia of both legs, constantly found in the L-4 distribution on the right but noted at times as high as D-12 on the left and L-1 on the right.

Laboratory Data: Blood studies and uranalysis were normal. The Wassermann was negative. Lumbar puncture between third and fourth lumbar vertebrae showed no evidence of block. The fluid showed a total protein content of 100 mg. per cent. The spinal fluid Wassermann was negative.

Myelography with pantopaque showed a block at the midportion of the fourth lumbar vertebrae. A small amount of the contrast material trickled by on the right side. (PLATE I, Fig. 3).

Laminectomy was performed, and a large herniated nucleus pulposus removed from the region of the fourth lumbar interspace (PLATE II, Fig. 2).

The postoperative course was uneventful. Four months after operation the patient was asymptomatic except for mild "lameness" in the back, and was working regularly.

Case 4.—A. B., S. M. H. No. 193284: The patient was a 56-year-old lastmaker, who was in excellent health until four months before admission, when he began to have severe pain in the back which would occasionally radiate down both legs. The pain increased in severity until he was forced to stop work seven weeks before admission. At this time he noticed weakness of the left leg associated with diffuse numbness on that side. Shortly before admission, the patient became bedridden by the pain. The pain was greatly aggravated by coughing and straining, by lying flat in bed, and by walking. His only treatment had been "hip-shots" and massage, from which he had no relief. For about five weeks before admission he noticed increasing difficulty in voiding, and a change in bowel habits. The past history was not remarkable.

Physical Examination: This revealed a muscular, elderly-appearing man in apparent pain. The positive findings noted were as follows: The prostate gland was slightly enlarged. There was bilateral lumbar muscle spasm without abnormal alignment of the spine. There was tenderness over sacrum and gluteal regions, somewhat more prominent on the right side. Pain was expressed on all movements of the back and on extension of the legs at the hips. The patient walked with a limp, necessitating the use of a cane. Straight leg-raising was permitted to 75° on the right and 90° on the left. There was hypesthesia over the lateral aspect of the left leg as low as the knee and over a small patch on the lateral aspect of the right knee. Patchy hypesthesia was reported as high as D-10 bilaterally. There was 1 cm. atrophy of the left leg as compared to the right. The left knee and ankle jerk were hypoactive.

Laboratory Data: The blood count, uranalysis, and blood chemistry were normal, and the Wassermann was negative. Lumbar puncture was attempted at the fourth lumbar interspace without success. Roentgenograms of the lumbar spine showed minor degenerative changes.

Myelography with pantopaque was carried out, revealing an almost complete block at the level of the fourth lumbar intervertebral space. A small amount of the contrast material trickled by the obstruction, as shown in PLATE I, Fig. 4.

Laminectomy was carried out, and a large midline herniated nucleus pulposus removed from the fourth lumbar intervertebral space transdurally (PLATE II, Fig. 3).

PLATE II.—The material removed at operation in Cases 2, 3, 4, 6 and 7 is shown here. The larger pieces of the tissue marked × represent that portion of the nucleus pulposus extruded into the spinal canal causing the compression. The material removed from each of two interspaces is shown in Case 7.

Postoperative course was uneventful, and the patient was asymptomatic three months after operation.

Case 5.—J. G., S. M. H. No. 181757: The patient was a 45-year-old exmechanic who, for 30 years, had had occasional shooting "numb sensations" down the left leg, noticed mainly after overexertion. For the past ten years, he had had five such episodes lasting approximately three days each. Two weeks before admission, coincident with a "cold" and cough, he developed severe low back pain. Two days later, the pain began to radiate down the left leg, then down the lateral aspect of the right leg, with associated numbness of both legs. He was confined to bed by the pain for two days prior to admission, and had great difficulty in urinating. The pain was sharp and shooting in character and aggravated by cough. It was not relieved by vitamin B injections, morphine, or bed rest.

Physical Examination.—This revealed a well-developed, well-nourished man, who appeared to be in some pain. General and neurologic examinations showed the following positive findings: The teeth were somewhat carious. There were a few coarse dry râles at both lung bases posteriorly. The patient was unable to walk. The spine was straight, with slight tenderness over the sacrum and right lumbar regions. There was bilateral tenderness in the posterior thigh regions. Straight leg-raising was markedly limited because of pain. Twitching was noticed in the glutei and calf muscles. The left thigh and calf were measurably smaller in circumference than the right. There was hypesthesia over both feet, the dorsum of the right calf, lateral aspect of the left calf, and of the saddle area. Vibratory sense was absent on the left. The right knee jerk was diminished and both ankle jerks were absent.

Laboratory Data: The blood count, uranalysis, and stool examinations were within normal limits. The Wassermann was negative. Lumbar puncture between the third and fourth lumbar vertebrae demonstrated normal dynamics, with a spinal fluid protein of 60 mg. per cent.

A chest film was not remarkable. Lumbar spine films showed some deviation to the left. Myelography with pantopaque showed a sharp cut-off in the subarachnoid space at the fourth lumbar interspace (PLATE I, Fig. 5).

Laminectomy was performed and a large herniated nucleus pulposus was removed extra- and transdurally. There was evidence of arachnoiditis on exploring the cauda equina, and microscopic section of the arachnoid showed round cell infiltration.

The postoperative course was uncomplicated. At the time of discharge the patient was asymptomatic. The only positive findings on physical examination were hypesthesia of the left foot and absent ankle jerks bilaterally. He did not return for follow-up.

Case 6.—E. J., S. M. H. No. 311831: The patient was a 28-year-old housewife, who first noticed pain in her right leg approximately ten years before admission, three months following an automobile accident in which she sustained no known injury. This episode lasted one and one-half years. She had similar but shorter attacks six and five years before admission, and following the latter she had operations upon both of her hip regions (probably fasciotomies). Subsequently she complained of repeated episodes of right hip and leg pain, on two occasions relieved by injections in her back. The last episode started approximately six months before admission, following which mild burning pain in the entire right leg on exertion was experienced. She also complained of an occasional twinge of pain in the left leg. Approximately one to two weeks prior to admission the patient noticed more severe pain in both legs associated with paresthesias and numbness in the right leg. Three days before admission, she became unable to void.

Physical Examination.—This revealed the following positive findings: On examination of the back, there was a list to the right, and considerable spasm of the paraspinal muscles. She experienced considerable pain on all movements of the back. Straight leg-raising was limited to 20° on the right and 30° on the left. There was 1 cm. atrophy of the right calf, associated with considerable weakness of all movements of

pieces of the tissue removed from each of two interspaces to obtain
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the foot, particularly with reference to plantar flexion. Mild atrophy was also noted in the left gluteal region and upper leg. Bilateral upper lateral femoral operative scars were present and there was an area of hypesthesia over the distribution of the left lateral femoral cutaneous nerve, which the patient stated had been present since her operation five years before. Hypesthesia was noted bilaterally in segments S-4 and S-5 and on the right in segments L-5 to S-3. Almost complete anesthesia was present over the outer aspect of the right foot. The right knee jerk was diminished and the right ankle jerk absent. The patient was unable to void and had to be placed on tidal irrigation.

Laboratory Data: Blood studies and uranalysis were normal. The serology was

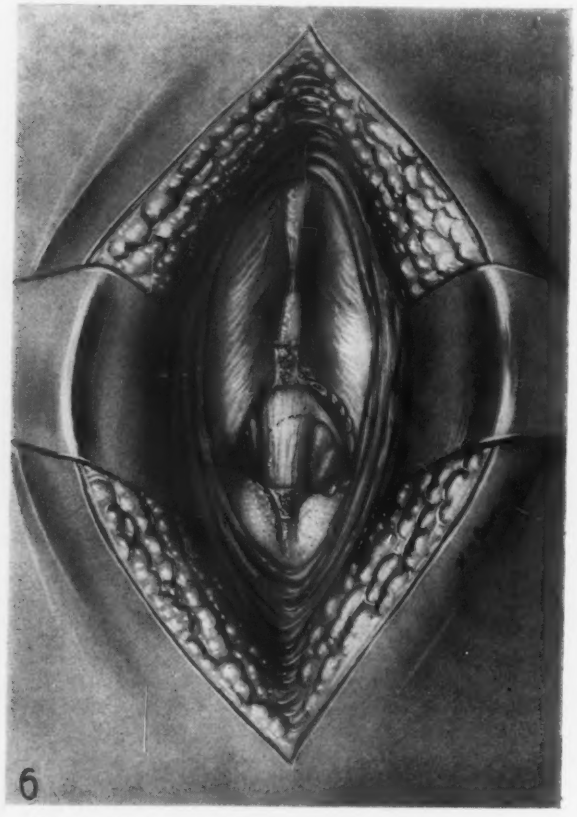

FIG. 2.—A diagrammatic representation of the pathology encountered in Case 6. The extruded nucleus pulposus is seen in the region of the fifth lumbar interspace.

negative. Roentgenograms of the spine showed narrowing of the fifth lumbar interspace. Spinal fluid protein was 90 mg. per cent. A pantopaque myelogram demonstrated a complete block at the fifth lumbar interspace (PLATE I, Fig. 6).

Laminectomy was performed (Fig. 2), and a large herniated nucleus pulposus removed from the fifth lumbar interspace (PLATE II, Fig. 4).

The postoperative course was uneventful. The patient was able to void spontaneously nine days after operation. When last seen, two months after operation, she was free of all discomfort and voiding normally. There was still slight weakness of the right plantar flexors. The right ankle jerk was absent, and there was hypesthesia over the outer aspect of the right leg and foot.

Case 7.—I. B., S. M. H. No. 211100: The patient was a 43-year-old tailor, with pain in the back and both legs of seven months duration. Seven months before admission he noticed the onset and progression of pain in the low back and down the backs of both legs, associated with parasthesias, weakness and coldness. These symptoms persisted, and about two months before admission he became unable to void. Subsequently, he catheterized himself regularly. Past history was pertinent in that patient reported an episode of weakness in the legs lasting for a month in 1928, treated by injections of calcium gluconate. No history of trauma was obtained. The patient had lost ten pounds in the previous six months.

Physical Examination.—The following positive findings were apparent: The spine showed a list to the left, with rather marked limitation of motion in all directions and spasm in the paraspinal muscles. These was some diffuse weakness of the anterior and posterior calf muscles but strength in general was quite good. Gluteal tone was very poor. There was anesthesia in the saddle area involving the S-4 and S-5 dermatomes, with a trophic ulcer on the left side in this area. There was complete retention of urine, and the rectal sphincter tone was very poor. Both ankle jerks were absent.

Laboratory Data.—Blood count was normal, and serology was negative. Uranalysis showed pyuria, with *Streptococcus hemolyticus* and *B. proteus* being isolated. Roentgenograms showed a relative narrowing of the lumbosacral interspace. Pantopaque myelography demonstrated a marked narrowing in the visualized column at L-4, and complete block at L-5 (PLATE I, Fig. 7).

At surgical exploration, a large herniated nucleus pulposus, completely compressing the dural sac, was removed from the L-5 S-1 interspace. A pathologic protrusion of the fourth intervertebral disk was also encountered and corrected (PLATE II, Fig. 7).

The postoperative course was one of gradual improvement. Pain had disappeared after about three weeks, and patient first began to void spontaneously about five weeks postoperatively. At this time, cystometry showed normal bladder response. When seen four and one-half months after operation, he still had 90 cc. residual after urination, and some constipation. He reported himself markedly improved but still had mild pain in the back although none was present in the legs. Hypesthesia was still present in sacral areas 3, 4, and 5, and there was mild weakness in plantar flexion on the right. The ankle jerks were absent.

Case 8.—A. B., S. M. H. No. 212371: The patient was a 36-year-old housewife. Four and one-half years before entry, she first noticed the onset of pain in the back associated with cramps and shooting pains in the left leg, increasing in severity. Three years before admission she had a severe episode of backache and pain in both legs, at which time she was studied elsewhere, and was in bed for two months. The pain was worse on coughing and sneezing. Subsequently, she was considerably improved although not completely without pain until about two months before entry, at which time the pain became progressively worse. She noticed that she would drag the right leg, and complained of numbness and tingling in the saddle area. She also noticed increasing urinary urgency and frequency, culminating in complete retention the day before entry. Past history developed that 18 years before admission the patient had her left kidney removed, apparently because of calculi. There were no subsequent urinary complaints until her admitting illness.

Physical Examination.—The following positive findings were present: The patient was confined to bed. There was flabbiness of the glutei and weakness of all movements of the right foot, particularly in plantar flexion. There was no difference in the size of the two legs. Straight leg-raising was limited to 20° on the right and 30° on the left. Saddle anesthesia was present involving S-4 and S-5, as well as the upper portions of the S-3 dermatomes on both sides. Tenderness was present in both gluteal folds. Both ankle jerks were absent. There was an old left flank operative scar.

Laboratory Data: Blood count and uranalysis were normal, and serology was nega-

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Physical Examination.—The following positive findings were apparent: The spine showed a list to the left, with rather marked limitation of motion in all directions and spasm in the paraspinal muscles. These was some diffuse weakness of the anterior and posterior calf muscles but strength in general was quite good. Gluteal tone was very poor. There was anesthesia in the saddle area involving the S-4 and S-5 dermatomes, with a trophic ulcer on the left side in this area. There was complete retention of urine, and the rectal sphincter tone was very poor. Both ankle jerks were absent.

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Laboratory Data: Blood count and uranalysis were normal, and serology was nega-

tive. Complete urologic studies revealed a normal functioning right kidney and an absent left kidney. Roentgenograms of the abdomen showed many calcified nodes on the left side. Cystoscopy showed a small projection of tissue at the vesicle neck (later removed) and some trabeculation of the bladder. Urine culture yielded *B. proteus* and *B. pyocyaneus*. Roentgenograms of the lumbar spine showed a relative narrowing of the fifth lumbar interspace. Spinal fluid protein was 200 mg. per cent, although a few red blood cells were reported present. Pantopaque myelogram shown in Plate I, Fig. 8.

At surgical exploration, a large herniated nucleus pulposus, completely compressing the dural sac, was removed from the lumbosacral interspace. Her postoperative course was uneventful. She began to void spontaneously approximately three weeks after operation. Four weeks after operation, she was ambulatory, without pain. The saddle hypesthesia had definitely diminished and she was able to walk easily. There was still some weakness of the right foot, and the ankle jerks were absent. Nine weeks after operation a letter from the patient reported mild stiffness in the back only, in spite of the fact that she was doing heavy housework. She reported herself otherwise in excellent condition.

DISCUSSION.—Relatively little is known concerning the incidence of extensive herniations of the nucleus pulposus because few cases have been reported. Camp,[1] in 1939, using lipiodol myelography, found that in 194 cases of proved "disks," 11.3 per cent had a partial block and 2.6 per cent complete obstruction of the subarachnoid space. In our experience, of 90 verified cases of herniated nucleus pulposus, there have been eight instances of subarachnoid block, as manifested by myelography, or an incidence of 8.8 per cent.

Other cases are reported in the literature, either singly or as illustrative examples. Dandy,[2] in 1929, reported two cases of block due to "loose cartilage" in the lumbar region, and described clinical manifestations closely simulating those presented here. Again, in 1942, he[3] reported three cases with block: One in the lumbar; one the dorsal; and one the cervical regions. Spurling and Bradford[4] described two cases, both at the fourth lumbar interspace, and a third case with obstruction due partially to protruded intervertebral disk and partially to arachnoid adhesions. Bunts,[5, 6] using thorotrast myelography, reported one case with complete block at the fourth lumbar interspace and, using lipiodol, two more cases of block in the region of the third lumbar interspace. Another case is described in the records of the Massachusetts General Hospital[7] in which a block was encountered at the fourth lumbar interspace.

In our patients, the lesion occurred at the interspace of L-3 in one case; L-4 in four cases; and L-5 in three cases. The age incidence varied between 28 and 62. Three patients were in the third decade, two in the fourth, two in the fifth, one in the sixth, and one in the seventh decades.

The duration of symptoms varied from three weeks to 30 years. In most of the cases, it is interesting to note that there was a long period of prodromal symptomatology culminating in a short, rapidly progressing period of incapacity just before entry into the hospital. In none of these patients was there a history of sufficiently severe single injury to be of associated importance to the patient.

History: The main complaints reported were pain, weakness, sensory disturbances and sphincter disorders. In three of the patients, twitching of the muscle of the legs was reported.

Pain was present in all patients. It was always the symptom of longest duration, usually beginning in the back and subsequently involving the legs. In all but one patient, it involved both legs. Usually, there was a long antecedent history of intermittent back pain for a period varying from seven months to 30 years, and a short period of three days to two months rapidly progressive bilateral leg pain, always of a severe nature.

Weakness of the legs was also a common complaint, being reported as such in five of the patients. It was sometimes difficult for the patient to evaluate weakness because of the pain. All but two patients were confined to bed at the time of hospital admission. In all but one case (Case 7) the weakness was a manifestation of the acute phase usually occurring a few days to a few weeks before admission.

Disturbances of sensation were reported in all cases but one (Case 3), and were, again, manifestations of the acute phase except in two cases (Cases 5 and 7). Usually the disturbance in sensation was described as numbness, but the terms "prickling," "coldness," and "tingling" were commonly used. These disturbances of sensation were reported in one leg in four cases; the saddle area and both legs in two cases; and only the saddle area in one case.

Disturbances of elimination were reported in all cases. This complaint was always a manifestation of the acute phase being present for as long as two months in only two cases. It was nearly always of rapid onset, occasionally being preceded by a few days of increasing difficulty in voiding or increasing constipation. Complete retention of urine was reported in three cases and of urine and feces in one case. Marked difficulty in voiding was present in two cases, and difficulty in voiding plus constipation in two cases.

Physical Examination: In all cases, there was evidence of weakness, atrophy, or poor muscle tone. This was not universally so extensive as might be expected, probably because of the relatively short duration of the acute phase of symptoms. Also, weakness was usually somewhat difficult to evaluate because nearly all of these people were in acute pain at the time of examination and, therefore, often restricted their effort. Atrophy of the glutei, thigh, or calf muscles was reported in four cases, and weakness and poor muscle tone in the same areas in the remaining four cases. The motor impairment was reported to be bilateral in four cases and unilateral in four cases. All but two patients were confined to bed.

Sensory disturbances were present in all cases. These changes varied considerably in extent and location but were universally bilateral. Disturbed sensation in the saddle area was common being present in five cases. This varied from dysesthesia to complete anesthesia, with trophic ulceration in one patient (Case 7). In two patients, sensory disturbances were reported as high as L-1 (Case 2), and D-10 (Case 4). In one of these patients (Case 2),

the lesion was found to be at L-3, and extensive arachnoiditis was encountered on opening the dura. In the remaining patients, sensory changes involved variously L-4 to S-5. Three of the patients with lesions at L-4 had portions of the L-4 dermatome involved. The greatest change, however, involved L-5, or below, in all cases.

The reflexes were altered in all cases. In five cases, the involvement was bilateral and in the remaining three unilateral. Alteration was uniformly present in the ankle jerks and, additionally, in the knee jerk in five cases. There were no cases of a single reflex being altered. In all cases, either both ankle jerks or a knee jerk and ankle jerk were impaired or absent. Those patients with pathology at L-3 and L-4 showed bilateral involvement in three cases and unilateral involvement in two cases. Of these, the knee jerk was impaired in all but one case. When the extrusion was at L-5, the involvement was bilateral in two cases and unilateral in one case, and the knee jerk was impaired in only one case.

Tidal drainage of the bladder was necessary in five patients, both before and after operation. Ability to urinate spontaneously returned in from nine days to five weeks, averaging two weeks. All patients with lesions at L-5 had complete retention while, of those with higher lesions, only two of five showed complete urinary sphincter involvement. The remaining three manifested varying degrees of difficulty in voiding.

Examination of the back was not well recorded in some instances, probably due to the acuteness of the patient's condition on entry. Tenderness was reported in four cases; spasm or limitation of movement in four cases; and no mention was made in one. Similarly, sciatic tenderness or sciatic stretch-tests were not well recorded, probably for the same reasons, although limitation in straight leg-raising was reported in five cases.

Roentgenograms of the back were taken in all cases—in one case elsewhere, but these films were reviewed by a member of the staff and reported to show nothing of significance. In two patients, a list was reported. In five patients, narrowing of an interspace was present, but in one of these (Case 2), the narrowing was not at the site of the proven lesion. Hypertrophic changes were reported in two patients (ages 62 and 56).

Spinal fluid protein determinations were made in six of the eight patients. The levels varied from 60 to 630 mg. per cent. The highest figure represents fluid taken from below the lesion (Case 2), and cisternal fluid on this same patient was 25 mg. per cent. In all other cases, the fluid was taken from above the lesion. In Case 8, a few red blood cells were reported present in the fluid.

Myelography was undertaken in all cases. In one instance this was done by cisternal puncture (Case 2); in the remaining cases by lumbar puncture. In all but one case (Case 2) pantopaque was used. In that one case, lipiodol was used. In all instances, complete, or nearly complete, block was encountered at the site designated. It was felt that this examination was a

good indication of the degree of obstruction because at body temperature, pantopaque has a low viscosity and flows readily. In one instance (Case 7), abnormalities were seen in two interspaces (L-4 and L-5) and at operation, an extruded nucleus pulposus was found at L-5 and a protruded intervertebral disk at L-4. There were no untoward reactions to myelography. The myelograms are shown in PLATE I.

Operative Findings: The early patients were all explored with a preoperative diagnosis of cauda equina tumor. Subsequently, the correct diagnosis was suspected and in the last three was the primary preoperative diagnosis. Recently, however, one patient with a very similar clinical picture was explored with the same preoperative diagnosis but was found to have metastatic carcinoma in the upper sacral segment.

The operative findings were similar in all cases: extruded nuclei pulposi severely compressing the dural sac were encountered and removed. The dura was opened in the first five cases. No mention was made as to the condition of the intrathecal contents other than they were "elevated to a marked degree" in two cases. In the remaining three cases (Cases 1, 2 and 5) thickening of the arachnoid, matting of the cauda equina, and adhesions were prominently present. In two of these cases (Cases 2 and 5) this was present to the extent that obstruction remained after removal of the extruded nucleus pulposus. Spinal fusion was done in three cases (Cases 1, 2 and 3).

Sequelae: All patients were relieved of their pain postoperatively, and were ambulatory and voiding spontaneously on discharge from the hospital. Stay in the hospital after operation varied from 17 to 77 days, the average being 36 days.—The longer hospitalizations were required for the patients who had spinal fusions. The average stay without fusion was 30 days. Two of the patients with fusions convalesced at home.

Follow-up varied from 2 to 16 months. One patient did not return. Three were operated upon within three months, and two of these had a two-month check-up. One patient (Case 1) had fairly extensive residual difficulty eight months after operation. She had weakness of her left foot, requiring use of a cane. There was also some vulvar anesthesia. Two others had a slight limp two months after operation (Cases 6 and 8). The remainder had no complaints when last seen. Two were reported working at their usual occupation, and one was simply reported asymptomatic.

CONCLUSIONS

The clinical similarity between herniated nucleus pulposus and early cauda equina tumors is generally well-recognized. The more advanced manifestations of neoplastic disease are, however, too often considered to be pathognomonic. The patients here reported suggest that herniated nucleus pulposus must be strongly considered even in the presence of advanced cauda equina compression. Herniated nucleus pulposus represents, indeed, in our experience, even a more common cause of such compressive manifestations than tumor. The differentiation between these two entities pre-

operatively is often impossible. The history and examination may present identical findings. All variations, up to complete block, may occur on lumbar puncture in both instances. Only the roentgenologic findings may be of differential aid. A narrowed interspace corresponding to a level of block at myelography should strongly suggest displaced intervertebral disk.

Another factor of possible importance in discogenic disease presented in these patients, is the presence of associated intrathecal inflammatory processes in the form of localized arachnoiditis. It was a very prominent manifestation in three of the five cases in which the dura was opened, and is possibly present to some degree in most of the cases. Some credence to this postulate might be taken from the universally increased spinal fluid protein encountered. A process of this type could possibly offer some explanation to such findings as sensory and motor changes corresponding to a level above the site of herniation as described in many of these patients. Further evidence of its possible importance was encountered in a recent case in which the patient developed rapidly progressing sensory changes, motor weakness, and sphincter involvement two weeks after removal of an uncomplicated displaced intervertebral disk. Repeat myelography demonstrated a complete block at the site of the operative removal instead of the original small defect. Reexploration four weeks after the original operation revealed no extradural pathology, but on opening the dura, an extensive localized arachnoiditis completely agglutinating the caudal filaments together was encountered. The symptoms and findings described disappeared during the next few weeks.

These patients may serve, also, to illustrate a possible danger in delaying operation for displaced intervertebral disk either because of faulty diagnosis or election. Nearly all had evidence of long preexisting discogenic disease yet the diagnosis was not made until all had evidence of extensive cauda equina compression. They were, thereby, subjected to extensively prolonged hospitalization and convalescence, and to the real possibility of crippling neurologic residuum. In view of the fact that many of these patients had minimal complaints prior to the acute episode culminating in cauda equina compression, it seems possible that any patient with discogenic disease might potentially suffer a similar fate. We feel this to be an argument in favor of myelography, certainly in equivocal cases and have used it routinely for two years.

SUMMARY

1. Eight cases of cauda equina compression due to herniated nucleus pulposus are presented. These cases are proven by myelography and operation.

2. This pathologic process was encountered at L-3 in one case; L-4 in four cases; and L-5 in three cases.

3. There is considerable similarity in the symptom complex presented by these patients. Their main complaints were pain in the back and both legs, numbness in the saddle area and/or both legs, weakness, and sphincter

disturbances. In most cases, there is usually a long antecedent history of back pain followed by an acute episode of rapid progression of the above symptoms.

4. The physical findings were also quite similar in all patients. The predominant findings were weakness or atrophy in the gluteal region or both legs, sensory changes in both legs, multiple reflex changes and sphincter abnormalities.

5. Narrowed interspace, determined roentgenologically, was frequently present, and of differential diagnostic importance when found.

6. Increased spinal fluid protein was the rule.

7. Myelography showed complete or nearly complete subarachnoid block in all cases.

8. The presence of marked subarachnoid inflammatory processes was demonstrated, and its possible importance in this condition discussed

9. The difficulty in differentiating this clinical entity from cauda equina tumor preoperatively is apparent.

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LUMBOSACRAL ROENTGENOGRAMS OF 450 CONSECUTIVE APPLICANTS FOR HEAVY WORK

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On several occasions the authors have sought information on the subject of just what one might expect to encounter in the roentgenograms of a group of so-called normal lumbosacral spines, and have noted a marked scarcity of information in the literature on this subject. The question has been raised as to what is normal in regard to slight deviations from the perfect anatomic specimen and, here again, there is little in the literature relating to this. A great deal has been written about abnormalities (anomalies, injuries, and diseases) found in roentgenograms of patients with symptoms, but few observations have been made concerning roentgenograms of people with no complaints.

It has been the privilege of the authors to study the roentgenograms of a series (consecutive) of lumbosacral spines in men applying for work, for the most part heavy labor, at a large industrial plant.* The results of this study were interesting as to the amount of gross abnormalities found and also the large number of cases showing slighter variations from the average normal. Because of the very high percentage of variation from the normal in these men who said they had no backache at the time they were seen or previously, it has seemed worth while to the authors to report this series.

It is of interest that the reason for taking routine low back roentgenograms of these patients was the industrial plant's previous unsatisfactory experience with litigation involving injuries to the lower back. In the year preceding starting the routine lumbosacral roentgenologic examinations, the industrial plant (a mine) had received several large adverse legal judgments in low back cases in which the allegedly injured individual had unquestionable previous pathology in some part of his lumbosacral spine. While no definite opinion can be expressed as yet, it appears that this type of litigation against the mining company is going to be greatly reduced since the introduction of the routine low back roentgenologic examinations, a saving which will far more than offset the cost of taking the roentgenograms.

The roentgenograms taken were of consecutive men applying for work,

* International Minerals and Chemical Corporation, Carlsbad, New Mexico.

which was for the most part heavy labor. It had been hoped originally to make the series 1,000 cases, but the study was interrupted by the enlistment into the Army of two of the authors. It is felt, however, that 450 represents a significant number.

The views taken were flat anteroposterior and lateral views, each 14 x 17 inches, centering over the lumbosacral joint, but usually extending from the 11th thoracic vertebra to the coccyx. Stereoscopic, localized lateral, oblique or angled anteroposterior views were not made because of the additional expense.

TABLE I

ANALYSIS OF ROENTGENOGRAMS OF 450 CONSECUTIVE LUMBOSACRAL SPINES IN APPLICANTS FOR HEAVY WORK

Pathology	Number of Cases	Per Cent
Hypertrophic changes: Severe	37	8
Mild	59	13
Total	96	21
Old compression fractures	22	5
Spondylolisthesis	14	3
Sacro-iliac arthritis: Severe	8	2
Mild	21	5
Total	29	7
Transitional vertebrae—with anomalous joint (unilateral 17 and bilateral 16)	33	8
Transitional vertebrae—with no anomalous joint (unilateral 8 and bilateral 5)	13	3
Total	46	11
Structural scoliosis	6	1
Increased lumbar lordosis	8	2
Lumbar ribs	39	9
Six lumbar vertebrae	8	2
Spina bifida occulta	29	6
Other miscellaneous anomalies	8	2
Osteoporosis	3	1
Foreign body (metal in soft tissue)	2	0.5
Wedging of lower thoracic or upper lumbar vertebrae: Severe	42	9
Mild	108	24
Total	150	33
Narrowing of lumbosacral interspace, posteriorly: Severe	103	23
Mild	140	31
Total	243	54
CASES WITH SOME TYPE OF PATHOLOGY	389	86
CASES WITH PATHOLOGY EXCLUDING MILD LUMBOSACRAL NARROWING AND WEDGING OF THORACOLUMBAR VERTEBRAE	249	31
CASES WITH MULTIPLE PATHOLOGY	222	49
CASES REJECTED FOR WORK (SEVERE PATHOLOGY)	68	15
ADDITIONAL CASES WITH SEVERE PATHOLOGY	37	8

Facet defects, pedicle defects, and other conditions were undoubtedly overlooked in this series because additional views were not available. The authors feel this is unfortunate but unavoidable, and had additional views been taken more pathology would have been found in all probability, and the scientfic value of this paper enhanced. This report is presented with

FIG. 1.—Hypertrophic arthritis of the lower lumbar spine. Note proliferative changes on the anterior margins of the vertebrae.

FIG. 2.—Spondylolisthesis. Note pedicle defects with forward displacement of the fifth lumbar vertebra on the sacrum.

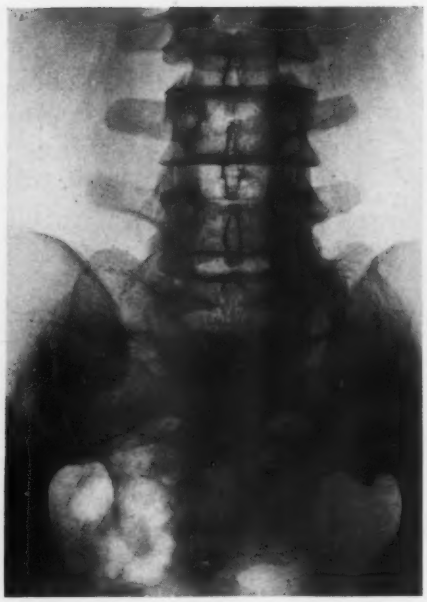

FIG. 3.—Sacralization of the fifth lumbar vertebra. Note the anomalous articulations between the transitional vertebra and the sacrum.

FIG. 4.—Old symmetrical wedging of the lower thoracic and upper lumbar vertebrae. This is usually due to an adolescent vertebral osteochondritis or epiphysitis.

the foregoing facts in mind and for what it is worth based on the views available. The films themselves were in some instances good rather than perfect, but if the films were definitely at all unsatisfactory retakes were made. The area covered was from the 11th thoracic vertebra to the lower sacrum.

The analysis of the series will be found in Table I. The pathologic conditions have been broken down rather minutely, and it will be noted that the only grouped cases are "other miscellaneous anomalies," which contain only eight cases. With this exception, every case is accounted for in a definite place. Table I is, for the most part, self-explanatory, and only a few comments seem indicated.

The types of pathology really group themselves into two categories: The first, consisting of the most serious types, includes hypertrophic changes (Fig. 1), old compression fractures, spondylolisthesis (Fig. 2), sacro-iliac arthritis, transitional vertebrae (lumbarized 1st sacral segment or sacralized 5th lumbar segment) with anomalous transverse processes (Fig. 3), and structural scoliosis.

The second group contains the conditions which are for the most part not so serious. This group includes increased lumbar lordosis, lumbar ribs, osteoporosis, foreign bodies, transitional vertebrae with no anomalous joint, anterior wedging of the body or bodies of the lower thoracic or upper lumbar vertebrae, and narrowing of the lumbosacral intervertebral space, posteriorly or generalized. The latter two conditions are worthy of special comment.

The old anterior wedging of the body of one or more upper lumbar or lower thoracic vertebrae is probably not often productive of symptoms (Fig. 4). It is of great medicolegal importance, however, for often roentgenograms are taken after an injury has been received which might produce a compression fracture, and a wedging noted. In these cases it is sometimes very difficult to be absolutely sure about when the injury was received, and if the case goes to litigation some medical witness may often be found who will testify it is recent. A preemployment roentgenogram will definitely settle this. The very high incidence of old wedging in our series (33 per cent) should add weight to the belief that symmetrical wedgings are of little or no clinical significance. It has been suggested that most of them are due to a vertebral epiphysitis or osteochondritis of adolescence.

The importance of narrowing of the lumbosacral interspace (and intervertebral disk) is the subject of some controversy. Symmetrical marked narrowing accompanies a transitional vertebra, and in these cases is part of the anomaly. The cases classed as severe narrowing (subluxation) are those in which there was very marked posterior narrowing of the joint space with backward displacement of the 5th lumbar vertebra on the sacrum (Fig. 5), and another group with marked symmetrical or posterior narrowing accompanied by sclerosis of the vertebral bodies in the areas closely adjacent

to the joint (marginal sclerosis). The cases classed as mild narrowing in this series are those with only a little narrowing and with little or no backward displacement of the 5th lumbar vertebra. With a quite definite narrowing of the lumbosacral joint space both anteriorly and posteriorly, or with marginal sclerosis of the adjoining vertebral bodies, they were not included in the mild group. Recently, a growing number of orthopedic surgeons (including the authors of this paper) have felt that lumbosacral subluxation is a common cause of low back pain. The fact that over one-half (54 per cent) of the cases in this series had posterior narrowing of the lumbosacral joint is not inconsistent with the above view, but it certainly indicates that the roent-

FIG. 5.—Posterior subluxation of the fifth lumbar vertebra on the sacrum. Note the marked downward and backward displacement of the fifth lumbar vertebra.

FIG. 6.—Multiple pathologic conditions. Traumatic wedging of the twelfth thoracic and first lumbar vertebrae; a small loose piece of bone on the anterosuperior margin of the fourth lumbar vertebra; and posterior lumbosacral subluxation—all in the same individual.

genogram alone is of little help in evaluating these cases as far as excessive joint motion is concerned. It is felt that mild or moderate posterior narrowing of the lumbosacral joint is normal, or at least a variant of the normal, since it is present in at least some degree in over one-half the men in this series.

It is interesting that in so large a series there were no cases of tuberculosis, osteomyelitis, or cases with a previous fusion operation. This would lead one to think individuals with these conditions either feel they are permanently disabled or are really so disabled.

The analysis of gross pathology is interesting in that altogether 86 per cent

of cases showed something that could be described. If the cases of mild wedging of vertebral bodies and mild lumbosacral narrowing are excluded (but still including those with lumbosacral narrowing accompanied with posterior displacement of the vertebra above, those with sclerosis of the vertebral margins, and those with transitional vertebrae), the percentage of pathology is 31 per cent. Of the original group, 49 per cent showed multiple pathology (Fig. 6), although many of these included lumbosacral narrowing or wedging of the upper lumbar or lower thoracic vertebrae.

Of the 450 cases, 15 per cent were rejected for work. The authors felt from the standpoint of the patients' roentgenograms they were very liberal in allowing such a high percentage to go to work, for many of those allowed to work showed considerable pathology, and a definite 8 per cent (additional to the 15 per cent) showed very marked pathology which might lead to trouble. Thus, there was the almost astonishing figure of 23 per cent of cases in which there were marked pathologic findings.

COMMENT.—This series of cases brings up a very real and important problem as to what pathologic conditions render a man unemployable in heavy industry, and the authors are not prepared to answer this question. It is probably an individual problem in each case. Such things as an old compression fracture with marked hypertrophic changes, or a spondylolisthesis, are potentially dangerous from the employer's standpoint as possibly productive of symptoms, compensation or litigation. The value of preemployment low back roentgenograms is certainly made clear in this series, and it is hoped more of these may be made and reported in the literature, by others.

SUMMARY

A series is reported of 450 consecutive lumbosacral spine roentgenograms taken in applicants for work in a heavy industry.

Table I summarizes the pathologic changes found—and a very high incidence was present. Thirty-one per cent of the cases showed significant pathologic changes, and in 15 per cent the pathology was severe enough to render them unemployable in heavy industry, in the authors' opinion.

The conditions present are analyzed and evaluated, and the great value of preemployment roentgenologic examination is pointed out.

COMPARATIVE VALUES OF VARIOUS METHODS OF RESUSCITATION*

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IN ANY ATTEMPT at resuscitation following asphyxia, there are two important and fundamental factors which may determine the outcome. The first is the prompt employment of the resuscitation procedure. The second is the inherent value or effectiveness of the procedure itself. Of the first factor, all investigators are agreed upon the necessity for the prompt application of the resuscitation procedure. Concerning the second factor, however, there are as many opinions as there are different methods of resuscitation.

It is important to keep in mind that respiration and circulation are intimately related and cannot act independently of each other for any length of time. Therefore, resuscitation procedures not only may have to be directed towards an adequate pulmonary ventilation but also towards an adequate circulation to carry the oxygen to the heart and brain. In asphyxia, however, the first efforts should be directed towards pulmonary ventilation.

In the minds of the laity as well as most of the profession there is still the belief that manual artificial respiration is the "procedure of choice" in asphyxia. Lougheed, Janes and Hall[1] in an excellent experimental investigation came to the conclusion that "as a result of our experiments we consider that prompt, adequate and prolonged artificial respiration is the fundamental treatment for drowned, asphyxiated or electrocuted persons."

Henderson and Turner[2] believe that manual artificial respiration is more effective than mechanical resuscitation. Coryllos[3] was of the opinion that the mechanical suck-and-blow resuscitator was superior to manual artificial respiration. Thus, the value of various resuscitative methods has been, and still is, a controversial subject.

Because of the conflicting opinions and the existing confusion, we have reviewed this problem and have attempted to clarify it experimentally by a critical comparison of the methods in ordinary usage.

These methods fall into two general groups: (1) Manual; and (2) mechanical. Our principal objectives were to compare the manual method with the mechanical methods and to determine the comparative values of the various methods.

In this investigation dogs were used throughout, and since a modified Sylvester method gave the greatest amount of pulmonary ventilation, only this method of manual artificial respiration was used.

All methods produce pulmonary ventilation in one of the following ways:

* Read before the New York Surgical Society, April 12, 1944.

(1) Positive inhalation and release produced by positive insufflation of the lungs; (2) deflation, produced by external compression or by negative suction; and (3) a combination of inhalation and deflation produced by positive insufflation alternating with negative suction deflation.

The manual method produces an active exhalation or deflation of the lungs. Inhalation is dependent upon muscle tone and the elastic recoil of the chest wall. The mechanical apparatuses are chiefly inhalators, insufflators and resuscitators. The insufflators produce an active inflation of the lungs. Deflation depends upon the elastic recoil of the lungs and chest wall. The resuscitators employ active insufflation alternating with suction deflation of the lungs and have either a volume or a pressure control. Whether it be a pump automatically operated or the anesthetic bag manually compressed, no apparatus, however simple, is devoid of the danger of alveolar rupture unless it has a pressure control feature and only those apparatuses with pressure control should be used. Simplicity does not always mean safety.

In comparing methods or mechanical apparatuses, it is desirable to have all conditions of the tests as nearly constant as can be, and the test itself should eliminate as many extraneous factors as possible. For this reason we have used the "asphyxial resuscitation test" as the method of comparison.

During the course of previous experiments in resuscitation we observed an interesting phenomenon, which, to our knowledge had not been previously described. We[4] described and called this "the phenomenon of asphyxial resuscitation." Briefly, it consists in the ability to regularly restore the circulation and respiration in advanced asphyxia, *without the benefit of oxygen,* by means of inflation alternating with suction deflation of the lungs, using an inert or asphyxiating gas (nitrogen, helium).

Paradoxical as it may seem, it is possible to resuscitate an animal in asphyxia from the inhalation of an inert gas (when respirations have stopped and the blood pressure is at or rapidly approaching zero) by the rhythmic inflation and deflation of the lungs, using the same gas which had just previously been used to produce the asphyxia. Resuscitation by this method is also possible in asphyxia produced by mechanical obstruction of the air passages.

Later experiments[5] showed this phenomenon to be a reflex from nerve endings in the lungs, carried by way of the vagi to the medullary centers. Adrian[6] has demonstrated in the lung the presence of nerve endings called "stretch receptors" which give rise to measurable action currents. They are unaffected by anesthetics or by a lack of oxygen and even cardiac cessation and circulatory failure have no immediate effect upon them. Their function is to signal the volume of the lung at each movement. One set of the end-organs is active only on inspiration or inflation of the lungs. Another totally different set is stimulated by suction deflation of the lungs. This latter set of end-organs is not stimulated by the normal expiratory or respiratory movements and there is no evidence of their activity in moderate dyspnea.

Forceful deflation of the lungs by external compression of the thorax in some animals is not enough to stimulate these end-organs. However, they do react quite readily to suction deflation. This provides a rather complete answer to the question of why suction deflation is necessary in resuscitation.

We have used the "asphyxial resuscitation test" because it completely eliminates the stimulating effect of oxygen and places the entire burden of resuscitation upon the method or apparatus itself. The test is made as follows: The animal (dog) is anesthetized with intraperitoneal nembutal. An endotracheal tube with occlusion cuff is inserted into the trachea, and the cuff is inflated. Under air-tight precautions a cannula is inserted into the pleural space. The femoral artery is cannulized. These two cannulae and the endotracheal tube are connected to separate recording mercury manometers which register upon a single revolving drum. The animal is now allowed to inhale, through the endotracheal tube, pure nitrogen gas, until asphyxia has progressed to a "critical point," in the third stage of asphyxia. This critical point is beyond the place where spontaneous resuscitation could occur and is determined by respiratory cessation, a rapidly falling blood pressure, and a slowing with irregularity of the heart. When this "critical point" is reached, the method or apparatus to be tested is put into operation; however, the endotracheal tube is still connected with the pure nitrogen gas. The method is applied until resuscitation occurs or the animal dies. Resuscitation is recognized by a sustained rise in the blood pressure and the return of spontaneous respiration. After the first spontaneous respiration has occurred, the endotracheal tube is disconnected from the nitrogen and is exposed to the atmosphere and all resuscitative measures are discontinued.

Asphyxia has been divided into four stages: Initial apnea, dyspnea, cessation of respiration or terminal apnea, and arrest of heart. Although it has been convenient to consider that the total duration of acute asphyxia is approximately four minutes, with each stage occupying about a minute, the actual duration of each stage and the total time may vary.

In evaluating resuscitation methods it is necessary to consider the possibility of spontaneous resuscitation and at what point it may occur in asphyxia. It was demonstrated by Coryllos[3] that when asphyxia of submersion is interrupted before the middle of the third stage, spontaneous resuscitation is possible; he considered that in obstructive asphyxia "removal of the obstructing agent before the end of the third phase is followed as a rule by spontaneous resuscitation. . . ." Since he considered his stages to occupy about a minute, this would place the critical point for spontaneous recovery less than 30 seconds from the time respiration ceased in the case of submersion asphyxia and less than 45 seconds from the cessation of respiration in the case of obstruction asphyxia. Lougheed, Janes and Hall,[1] in a study of asphyxia by drowning and tracheal obstruction, have found that after cessation of respiration there is a critical point at which the heart beat ceases to be expulsive. In general, the point at which respiration ceased and the point at which the asphyxial procedure was stopped could not exceed

18 seconds if spontaneous recovery were to take place. If this period was extended even a very few seconds longer, resuscitation would be impossible.

We[7] have shown that asphyxial resuscitation (using an inert gas) is possible far beyond the point in asphyxia where spontaneous recovery could take place. Generally, we have started asphyxial resuscitation well beyond the 45-second point of the third stage of asphyxia at a variable "critical point" where the heart action becomes altered and irregular. The length of time which may elapse between respiratory cessation and the successful application of asphyxial resuscitation varies in each experiment; the longest interval was two and three-quarter minutes. In the usual resuscitation experiment, the circulation recovers first followed by the recovery of respiration. Even though the circulation has recovered, the method is usually continued in action until spontaneous respiration has taken place, although this is not always necessary.

TABLE I

EFFICIENCY OF DIFFERENT RESUSCITATIVE PROCEDURES

Nitrogen

	Success	Failure	Per Cent of Sucess
1. Manual artificial respiration	1	6	15
2. Rhythmic inflation	2	10	17
3. Rhythmic suction	1	4	20
4. Resuscitation (rhythmic inflation and suction)	30	5	85

Comparing various methods of resuscitation[8] by this test (Table I) we found manual artificial respiration was successful in 15 per cent; inflation-and-release was successful in 17 per cent; suction deflation-and-release was successful in 20 per cent; combined inflation alternating with suction deflation was successful in 85 per cent.

TABLE II

EFFICIENCY OF DIFFERENT RESUSCITATIVE PROCEDURES

Oxygen

	Success	Failure	Per Cent of Success
1. Manual artificial respiration	6	5	55
2. Rhythmic inflation	7	2	78
3. Rhythmic suction	4	1	80
4. Resuscitation (rhythmic inflation and suction)	21	1	95

When the tests were repeated, using, however, oxygen (100 per cent) instead of the nitrogen during the period of resuscitation (Table II), we found manual artificial respiration was successful in 55 per cent; inflation-and-release was successful in 78 per cent; suction deflation-and-release was successful in 80 per cent; combined inflation alternating with suction deflation was successful in 95 per cent.

Interpretation of these results shows the marked superiority of mechanical over manual methods of resuscitation. Further analysis of these results shows the importance of using suction deflation in resuscitation procedures

since suction alone was more successful than either manual artificial respiration or inflation and release. These results also show the superiority of mechanical resuscitators using inflation alternating with suction deflation, over all other methods.

CONCLUSIONS

Since the prompt application of the resuscitative procedure is of prime importance and since manual artificial respiration is usually the only method at hand; it is suggested that in asphyxia, manual artificial respiration be immediately applied and continued until a mechanical resuscitator using safe pressure can be substituted. The importance of using suction deflation in resuscitation has been shown. Those resuscitators employing both insufflation as well as negative suction deflation are the most efficient of the mechanical apparatuses and gave the largest percentage of successful resuscitations. It is recognized that all methods of resuscitation are dependent upon patent air passages.

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STUDIES ON SURGICAL CONVALESCENCE*

I—SOURCES OF NITROGEN LOSS POSTGASTRECTOMY AND EFFECT OF HIGH AMINO-ACID AND HIGH CALORIC INTAKE ON CONVALESCENCE

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In a preliminary communication on this subject[1] it was reported that patients convalescing from gastrectomy, when fed with a high caloric and high amino-acid diet (nutramigen) were able to maintain a consistently positive nitrogen balance throughout the postoperative period; to register a rise in body weight; and to achieve an early return of strength and a significantly shortened convalescence. This picture was in striking contrast with that of a similar group of postoperative patients under the classical postoperative ward regimen, who had a consistently negative nitrogen balance, a loss of body weight, a longer period of postoperative debility, and a more prolonged stay in bed.

The present series may be considered a continuation and further development of the previous work. Of the 19 cases reported here, eight (Group A) were on routine ward regimen, eight (Group B) were fed high caloric and high amino-acid mixture, and an intermediate group of three (Group A′) were fed, but not in enough quantities to maintain nitrogen equilibrium. Seven in A, six in B, and all the three in A′ had complete nitrogen balance studies for from seven to 12 days. Three patients each in A and B had ergographic tests performed.

EXPERIMENTAL CONSIDERATIONS

The conditions under which the present study was carried out were, in the main, similar to those in the first series. The following modifications were made in the light of additional experience:

(1) *Types of Cases.*—Unlike the former series which eliminated cases with complications, except wound infections, the present series was a random one in which cases with as well as without complications were included.

(2) *Use of the Abbott-Rawson‡ (AR) Tube.*—In the present work the

* The work described in this paper was done under a contract recommended by the Committee on Medical Research between the Office of Scientific Research and Development and New York University and read in abstract form before the Committee on Convalescence and Rehabilitation of the National Research Council, November 16, 1943.

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‡ The Abbott-Rawson tube is manufactured by George P. Pilling & Son, Arch and 23rd Streets, Philadelphia, Pa.

AR tube, which was devised by Abbott-Rawson[2] for a similar purpose but which has been modified by leaving out the metal bucket, was used instead of the modified Miller-Abbott used in the former series. The larger bore of the AR tube facilitated feeding and the lighter weight of the jejunal portion of the tube minimized the possibility of erosion of the tissues at the anastomosis. The construction and use of the tube is shown in Figure 1.

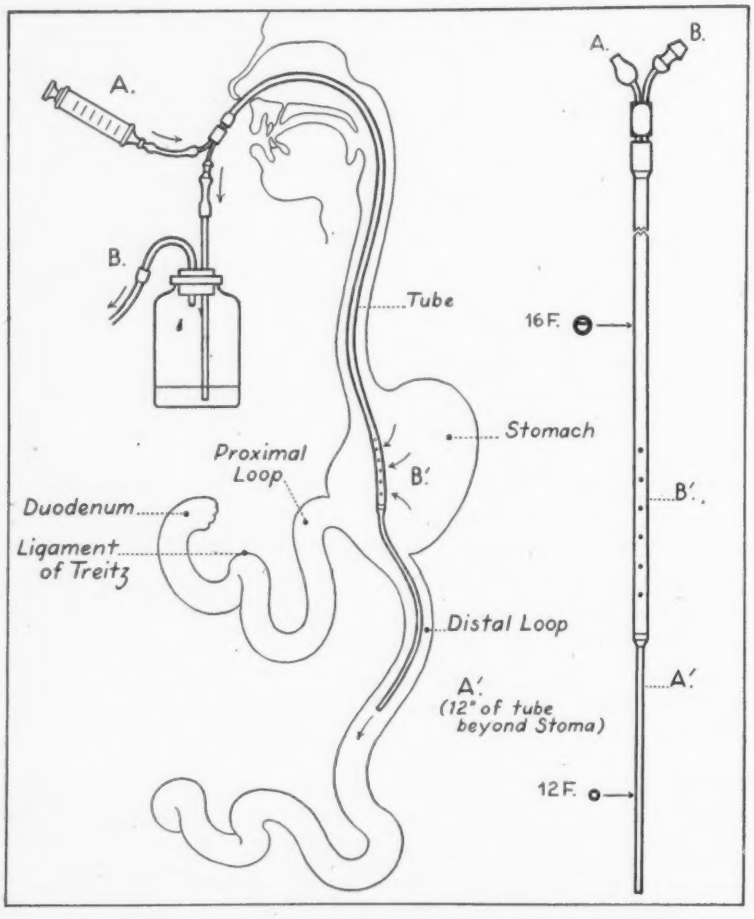


FIG. 1.—A line drawing showing the use of the Abbott-Rawson tube in gastrectomy cases.

Having been tested for patency and autoclaved, the tube was passed into the stomach through one of the nares the night before the operation. The next morning, one hour preoperatively, the stomach was emptied by suction through both lumens of the tube. During the operation and at that stage of anastomosis between the stump of the stomach and the jejunum when the row of hemostatic sutures had reached halfway round the anterior aspect of the stoma, the anastomosis was interrupted in order to pass the feeding end of the AR tube into the jejunum. This was done under aseptic pre-

cautions. The assistant grasped the distal loop of the jejunum for a distance of 12 inches, holding it up between the fingers of both hands. The surgeon inserted a pair of long sponge-forceps through the anastomotic opening into the lumen of the stomach and, by locating the tip of the tube with his free hand from the exterior of the stomach wall, he picked it up with the sponge-forceps. The forceps, with the tip of the tube in the jaws, were withdrawn from the stomach and inserted into the distal loop of the jejunum until the junction of the gastric and jejunal portions of the tube lay just proximal to the anastomosis. The assistant, by palpating through the jejunal wall then located the tip of the tube and held it in place while the surgeon disengaged and withdrew the forceps, which were then discarded. The operative work was then resumed.

Postoperatively, for from four to six days, as indicated, Wangensteen suction was maintained through the suction lumen of the AR tube, thus keeping the stomach empty.

The fluid and caloric intakes were governed by the Coller and Maddock[3] principles.

(3) *The Caloric Intake.*—In A the caloric intakes were all subbasal, consisting solely of the infusions of dextrose in the first five to six days, and of the sugar in tea and the peptonized milk given in subsequent days. In A' the intake was almost basal, while in B it was never under 2,000 daily (50 calories per kilogram body-weight), consisting in the first five to six days of amigen and dextrimaltose, and in the balance of convalescence usually also of the fat present in nutramigen.

(4) *Use of Digestate Mixtures.*—In the former series nutramigen was used exclusively. Nutramigen contains the casein digestate, amigen, reinforced with dextrimaltose, starch, fat, salts and yeast powder. It yields 4.7 calories and 0.027 Gm. of nitrogen per Gm. The salts contribute to the mineral balance and the yeast powder presumably furnishes the vitamins. This mixture has been used in pediatrics as the sole nutriment for infants and babies for over five years.[4] Its composition, however, makes it difficult to make a stable instillable suspension; and during the first four or five days postoperatively, when it may become necessary to use a high nitrogenous feeding in small volume, nutramigen is unwieldy.

Amigen which is more soluble, more easily maintained in suspension, and contains much more nitrogen, is, therefore, indispensable. It yields 3.4 cals. per Gm., and contains 12 per cent nitrogen. Aside from sodium chloride, no other constituents are present. The nitrogen requirements are first calculated (0.6 Gm. N per the Kg. body-weight) and then dextrimaltose was added in sufficient amounts to make up the requisite caloric intake. Recently, it has been our practice in many cases to use amigen-dextrimaltose mixtures during the first five to six postoperative days, adding nutramigen after the AR tube was removed. It was thought desirable to do this in order not to deprive the patients of essential fatty acids for too long a period of time. This use of varying amounts of amigen and dextrimaltose also permits a

greater elasticity in the adjustment of nitrogen and caloric intakes, a problem which is sometimes difficult when either powder is used exclusively.

Amigen and dextrimaltose mixtures, because of their high solubility, and lack of "body," may be made with any volume of water. With nutramigen, which is less soluble, the use of 1 cc. of water per Gm. of the substance makes an easily instillable mixture. When amigen and nutramigen are used in the same formula, the use of 1.2 to 1.5 cc. of water per Gm. of nutramigen usually was enough to take the amigen into solution as well.

The powdered ingredients were weighed and mixed together in a mixing bowl. The calculated volume of hot water was then measured and poured into the powder, stirring all the time. After thorough mixing, the mixture was poured into milk bottles and placed in the refrigerator at approximately 40° F.

(5) *The Nitrogen Intake.*—In A, the only nitrogen intake during the first days postoperatively was in the form of blood or plasma transfusions. Other than this, during the first five days it was almost *nil.* From the sixth day on, small gradually increasing amounts of peptonized milk constituted the entire nitrogen intake. At about the tenth day, more substantial food was added, the nitrogen content of which was calculated from the dietitian's chart.

The patients in B derived their nitrogen intakes from the amigen or nutramigen given, the usual nitrogen intake being in the neighborhood of from 0.4 to 0.6 Gm. per Kg. body-weight, the latter amount exceeding the intake of a high protein diet by 1.5 to 2.2 times. The patients in A′ were also fed either amigen or nutramigen, or both, but in quantities not sufficient to maintain caloric or nitrogen balance.

(6) *The Feeding Schedule.*—It may be helpful to set forth in some detail the feeding regimen as now practiced in the feeding cases. For the first 6 to 12 hours postoperatively, infusions of 5 per cent amigen in physiologic saline and dextrose solutions were given. After that, for the cases in which the surgeon was sure of the flawlessness of his technic, feeding was started, beginning from 30 cc. per hour for the first four to six hours to 50 cc. every hour for the remainder of the first postoperative day. The volume was increased from 60 to 90 cc. on the second day and from 90 to 100 cc. thereafter. The following is a sample schedule:

R. B., Age 48, Weight 63 Kg.

P. O. Day	By Tube–Gm.	By Vein–Gm.	N. Intake Gm.	N. Gm./Kg.	Caloric Intake
		Plasma 250 cc.	8.8	0.14	1040
		Amigen 50			
1	0	Glucose 200			
	Amigen 250	Amigen 100			
2	D. M. 500	Glucose 150	42	0.67	3815
3	Same	Amigen 50			
		Glucose 150	36	0.57	3560
4 to 11	Amigen 350				
	D. M. 600	0	36	0.56	3420

It will appear from the above schedule that, during the first day, the caloric and nitrogen intake, when only intravenous infusions were given the first six to twelve hours, followed by 30 to 50 cc. of oral feeding every hour, as restricted by the restriction in fluid intake and that intravenous feeding barely made up caloric and nitrogen requirements. On the second day the tube feeding alone yielded a sufficient caloric and nitrogen intake, but was insufficient for fluid replacement; and, therefore, intravenous medication had to be given. On the third day, the intravenous fluid supply was reduced to one liter, and after the fourth day this was dispensed with, the entire caloric, nitrogen and fluid requirements having been supplied through the tube.

It will be recalled that, in our first series of cases, it was possible to dispense with intravenous fluid therapy altogether, thereby saving the patient a great deal of discomfort. To do this, however, meant increasing the volume fed by tube to from 100 to 150 cc. an hour, starting after the first 12 hours. This large volume of feeding for the first postoperative day would not be easily acceptable to the average surgeon. For this reason, and for the reason that the patients under this more conservative regimen did not seem to fare any worse, the above compromise feeding schedule is recommended. In the ultimate analysis, a rigid program will only be rejected by most of the surgical profession and, thus, defeat its own purpose.

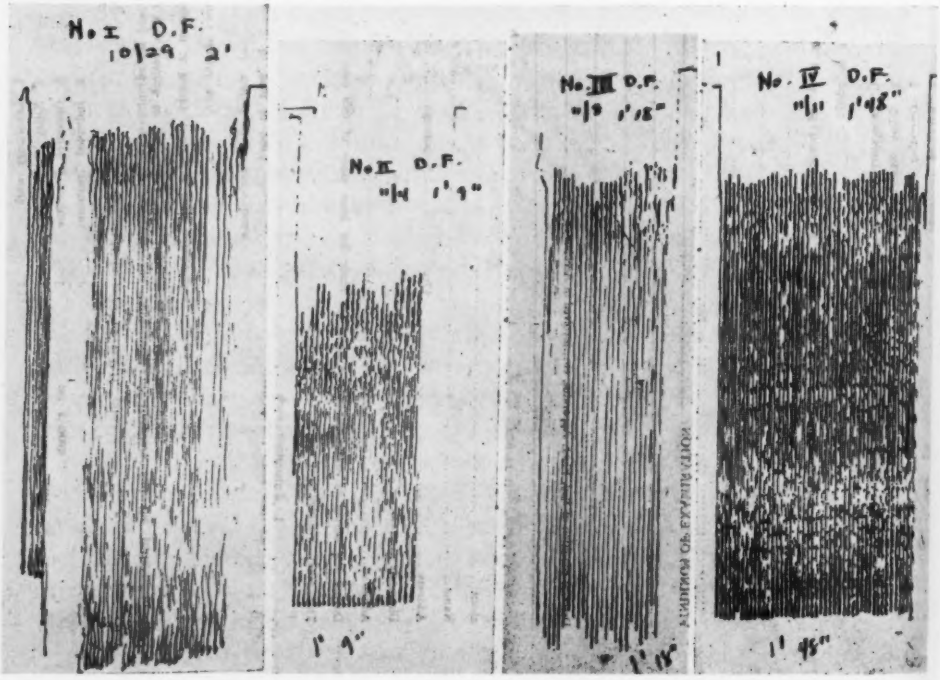
(7) *Vitamin Intake.*—Throughout convalescence, beginning from the first postoperative day, the following complement of vitamins was given intramuscularly: Thiamine chloride, 50 mg.; ascorbic acid, 100 mg.; niacin, 50 mg. After the fifth day, these were given by mouth.

(8) *Management of Distention and Diarrhea.*—The incidence of early distention in this series is unusually small in all groups. When distention persists after the first 48 hours, small doses of prostigmin in combination with the Harris drip rapidly reduced it. In not one of the eight full feeding cases in this series was it necessary to discontinue feeding as a result of distention.

In our former series when nutramigen was fed, diarrhea sometimes ensued after the first two or three days of feeding. This was perhaps due to the presence of fat in the nutramigen. In the present series, using an amigen-dextrimaltose feeding mixture, whatever tendency to diarrhea was present was controlled by the routine administration of amphojel, 4 cc. four times daily, by the tube the first two days and by mouth thereafter. Occasionally this was supplemented by small doses of paregoric.

(9) *Ergography.*—The bedside ergograph, the construction and use of which has been described in a separate paper,[5] was used to test the endurance of the patients preoperatively and periodically, postoperatively in three patients in A—D. F., Table V; F. Mc., Table VII; and M. K., Table VI: three in B—R. B., Table XVI; C. N., Table XIV; and A. V., Table XIII. This was an attempt to study objectively whether there was asthenia in the control cases and early return of the patients' strength in the feeding cases—possibilities strongly suggested by our first series.

A short description of the test may not be amiss. The upper extremity was placed on the board of the ergograph so that the forearm was free. Through a cable and a set of pulleys, a weight of either 3, 5, or 10 Kg., depending upon the robustness of the patient, was lifted and lowered, the excursions being registered on a moving drum. These efforts were spaced every three seconds, and at the point when the patient felt painful fatigue in the arm, the lifting was discontinued. This was the end-point. The length of the entire test from the beginning of the first to the end of the last excursion is expressed in seconds and is called the ergograph-time (E. T.).



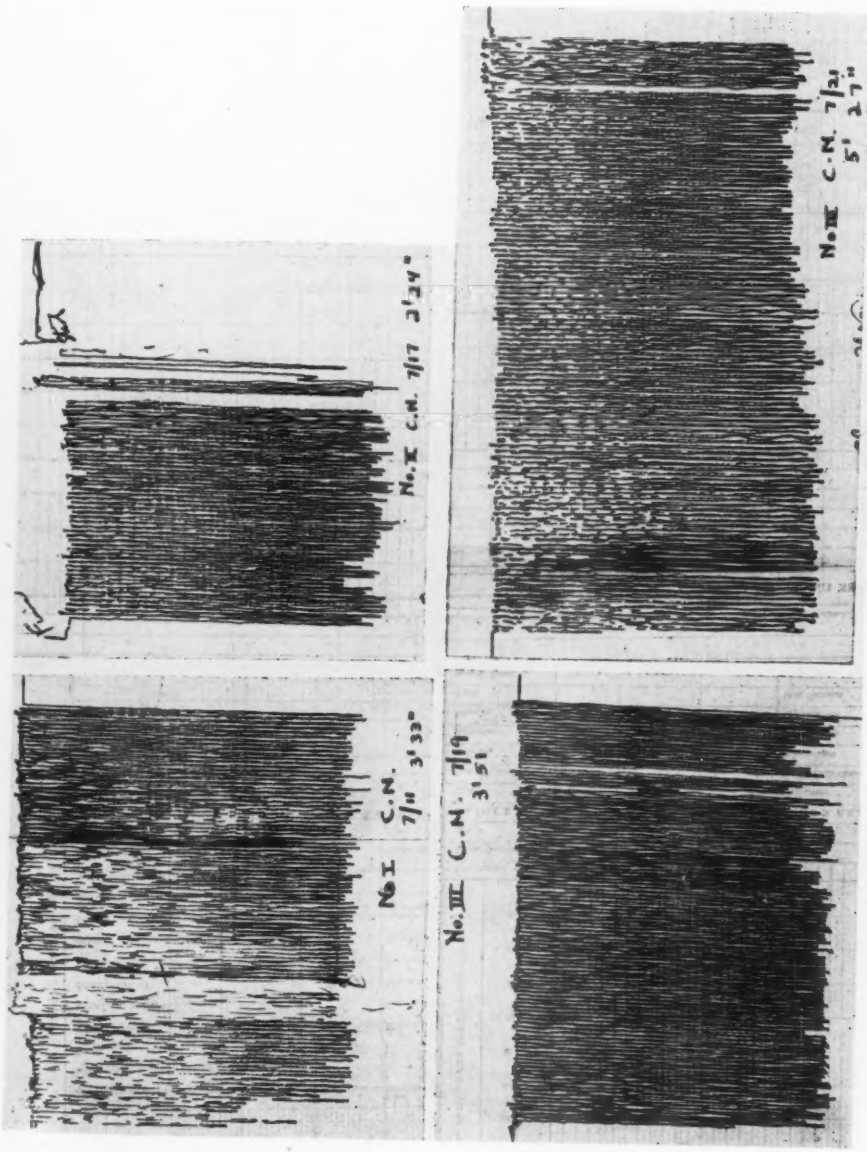
GRAPH 1.—The ergograph-time of patient D. F. (Table V) under postgastrectomy ward regimen. Note that the initial ergograph-time in Panel I was 2', that Panel II on the fourth postoperative day, showed a depression to 1'9", and that in Panels III, and IV, taken, respectively, on the 8th and 11th postoperative days, the ergograph-time had not reached the initial value.

Graphs 1 and 2 show the ergographs of a control compared with a feeding case.

(10) *Collection and Care of Specimens.*—The urine and feces were collected according to the directions given in the preliminary report. The chemical methods used were also the same as those used in that series.

ANALYSIS OF THE TABLES

There are presented for analysis, 16 individual tables (Tables I to XVI) each recording the nitrogen intake and output, the nitrogen balance, the cumulative nitrogen status, the plasma proteins, the hematocrit, the weight, and the immediate postoperative history of the patient. For purposes of simplification, the columns on fluid output, and volume of gastric drainage



GRAPH II.—The ergograph-time for C. N. (Table XIV) under high alimentation regimen. Note that there was a depression of the ergograph-time in Panel II, on the 6th postoperative day, but that in Panel III, on the 8th postoperative day, the initial value had been exceeded.

have been omitted. These figures differed very little from those of the previous series except that in one case (M. K., Table VI), in whom there was frank postoperative hemorrhage, and in two cases (A. S., Table VIII), and W. C., Table IX, in whom hemorrhage was suspected, the volume of drainage resulting from the gastric suction was unusually large.

TABLE I

G. W., MALE, 58—CARCINOMA PYLORUS

			Nitrogen Output									
Date	Daily N. Intake Gm.	Total N. Intake Gm.	Urinary N. Gm.	Gastric N. Gm.	Fecal N. Gm.	Total N. Output Gm.	N. Balance Gm.	Cum. N. Status Gm.	P. P. Gm. %	Hem.	Wt. Kg.	Remarks
Jan. 12									6.3	41	54.81	
13–14	0			2.5								Gastrectomy.
14–15	0	2.8	24.66		1.44	28.60	−25.72	−25.72				500 cc. W.B.
15–16	2.8								5.56	39		
16–17	2.85			1.3								
17–18	3.8	9.42	21.45		1.44	24.19	−13.39	−39.19	5.67	39		
18–19	2.77										53.45	
19–20	3.8	3.8	15.50		.48	15.98	−12.18	−50.37				
20–21	6.8	6.8	7.6		.48	8.16	− 0.84	−52.21			52.96	
21–22	6.8	6.8	7.16		.48	7.64	− 0.36	−52.57				
22–23	6.8	6.8	7.6		.48	8.08	− 1.28	−53.85				
23–24	7.15	14.30	19.17		.96	20.13	− 4.83	−58.68			51.82	
24–25	7.15											
26											50	
30											49.55	Out of bed—17th day
Total	50.72		103.4		5.76	112.78						Disch. to sanitarium—(19th. day)
Avg.	4.23		8.62		.48	9.39						

TABLE II

A. D., MALE, 59—DUODENAL ULCER

			Nitrogen Output									
Date	Daily N. Intake Gm.	Total N. Intake Gm.	Urinary N. Gm.	Gastric N. Gm.	Fecal N. Gm.	Total N. Output Gm.	N. Balance Gm.	Cum. N. Status Gm.	P. P. Gm. %	Hem.	Wt. Kg.	Remarks
March 5									6.12	42	62.25	
6–7	17.5	24.75	31.88	6.55	.44	38.87	−14.12	−14 12				Gastrectomy
7–8	7.25											500 cc. W.B. and amigen
												Temp. 102.8°
												Pulmonary atelectasis
8–9	0	.85	27.85	11.57	.44	39.86	−39.01	−53.13	6.71	43		Temp. 102.6°
9–10	.85											Temp. 101.4°
10–11	1.32			6.38								Temp. 102.2°
11–12	1.82	6.78	36.48		.66	43.53	−36.74	−89.87				Temp. 102.5°
12–13	3.64											Temp. 101.8°
13–14	3.11											Temp. 102.4°
14–15	3.4	10.71	33.88		.66	34.54	−23.83	−113.7				Temp. 101.6°
15–16	4.2									37	57:72	Temp. 102°
Avg.						13.68						Temp. normal
25												Out of bed (19th day)
31												Discharged to sanitarium (25th day
Total		43.09	130.09			2.2	156:8					
Avg.		4.31	13.01		:22	15.68						

TABLE III

T. S., MALE, 64—DUODENAL ULCER

Date	Daily N. Intake Gm.	Total N. Intake Gm.	Nitrogen Output: Urinary N. Gm.	Gastric N. Gm.	Fecal N. Gm.	Total N. Output Gm.	N. Balance Gm.	Cum. N. Status Gm.	P. P. Gm. %	Hem.	Wt. Kg.	Remarks
March 23												Gastrectomy.
23–24	2.8	2.8	23.12	9.06	1.0	33.18	−30.38				55.5	500 cc. W.B.
24–25	0											
25–26	0			10.3								Fever 101°
26–27	0	0	36.99		1.5	48.79	−48.79	−79.17	4.52	24		Fever
27–28	0											Fever
28–29	4.3										52.1	Fever to 10th day
29–30	4.2	13.7	29.04		1.5	30.54	−16.84	−96.01				
30–31	5.2											
April 1									4.39	30		
11											49.05	
											48.3	Out of bed (18th day)
13												Discharged (20th day)
Total		16.5	89.15		4.0	98.81						
Avg.		2.1	11.14		.5	12.35						

TABLE IV

P. B., MALE, 34—DUODENAL ULCER

Date	Daily N. Intake Gm.	Total N. Intake Gm.	Nitrogen Output: Urinary N. Gm.	Gastric N. Gm.	Fecal N. Gm.	Total N. Output Gm.	N. Balance Gm.	Cum. N. Status Gm.	P. P. Gm. %	Hem.	Wt. Kg.	Remarks
April 1									6.25	42	64.32	Gastrectomy
1–2	2.8	2.8	12.28	9.09	1.00	22.37	−19.47					500 cc. W.B.
2–3	0											
												Fever 102°; chills
												Mucopurulent expectoration;
												X-rays negative
3–4	0											Fever between
4–5	0	0	24.2	9.29	1.5	34.99	−34.99	−54.46				101-103° to 12th
5–6	0											P.O. day
6–7	6.8			3.8								
7–8	6.2	19.45	38.4		1.5	43.7	−24.25	−78.71	6.04			
8–9	6.45											
11												
24											60.05	
												Out of bed (23rd day)
May 11									5.99	37		Discharged (39th day)
Total		22.25	74.88		4.0	101.06						
Avg.		2.78	9.36		.5	12.63						

TABLE V

D. F., MALE, 55—CARCINOMA PYLORUS

Date	Daily N. Intake Gm.	Total N. Intake Gm.	Nitrogen Output: Urinary N. Gm.	Gastric N. Gm.	Fecal N. Gm.	Total N. Output Gm.	N. Balance Gm.	Cum. N. Status Gm.	P. P. Gm. % or A/G	Hem.	Wt. Kg.	Remarks
Oct. 30									3.31/1.92	32	59	Erg. T.—120 sec.
30–31	2.4											Gastrectomy—
Nov.		4.8	19.03	2.89	.82	22.74	−17.94					2 units plasma
31–1	2.4											
1–2	2.4								5.17	42		Erg. T. 69″.
		2.4	20.46	6.52	1.23	28.21	−25.81	−43.75	5.11			Temp. rise in P.M. to 102°
2–3	0											Febrile
3–4	0											Febrile
4–5	2.2											Wound infection
5–6	2.2	8.6	17.23		1.8	19.03	−10.43	−54.18				Erg. T.—78″
6–7	4.2											Wound still discharging
7–8	4.2	8.4	20.82		1.2	22.02	−13.62	−67.80	5.09	39		
8–9	4.2											
9–10						9.2						Temp. normal. Erg. T.—108″
13											50	
17												Out of bed; weak (18th day)
19												Discharged (20th day)
Total	24.2	77.54	5.05		92							
Avg.	2.42	7.75	.5		9.2							

TABLE VI

M. K., MALE, 55—DUODENAL ULCER

Date	Daily N. Intake Gm.	Total N. Intake Gm.	Nitrogen Output: Urinary N. Gm.	Gastric N. Gm.	Fecal N. Gm.	Total N. Output Gm.	N. Balance Gm.	Cum. N. Status Gm.	P. P. Gm. %	Hem.	Wt. Kg.	Remarks
Dec. 15									5.62	41	68	Erg. T.—398″ Gastrectomy 500 cc. W.B.
16–17	14.8											Gastric hemor-
17–18	12	32.6	51.86	13.71	2.2	67.77	−35.17					rhage, 500 cc.
18–19	5.8											W. B.
19–20	14.8											Temp. 104°;
20–21	2.2	19.2	69.6	14.93	1.27	85.80	−66.6	−101.77				slightly icteric
21–22	2.2											Erg. T.—299″
22–23	4.2								5.62	30		Febrile
23–24	4.2	14.6	41.2		1.27	57.07	−42.47	−144.84				Temp. normal
24–25	6.2											
28											61.81	Erg. T.—300″
Total		66.4	162.66		4.74	210.64						Out of bed (13th day)
Avg.		7.4	18.07		:53	23.40						

TABLE VII

F. MC., MALE, 46—DUODENAL ULCER

Date	Daily N. Intake Gm.	Total N. Intake Gm.	Nitrogen Output: Urinary N. Gm.	Gastric N. Gm.	Fecal N. Gm.	Total N. Output Gm.	N. Balance Gm.	Cum. N. Status Gm.	P. P. Gm. %	Hem.	Wt. Kg.	Remarks
May												Erg. T.—114″
7									5.48	33	52.5	Gastrectomy, May 8. 2 units plasma
8- 9	2.4											Temp. 102.6°
9-10	2.4	4.8	22.42	3.38	3.51	29.31	−24.71					Febrile
10-11	0								5.09	30	49.09	Febrile
11-12	0											Febrile
12-13	0	0	27.32	2.07	3.51	32.90	−32.94	−57.65				Febrile
13-14	0	0										Febrile
												Erg. T.—42″
14-15	1.2								5.81	32		Temp. normal
14-15	2.2	7.2	24.14		3.51	27.65	20.45	−78.10				
16-17	3.5											
17-18	3.8											
18-19	4.4	12.6	27.65		3.51	31.16	−18.56	−96.66	5.53	33		
19-20	4.4										47.95	Erg. T.—84″
25											47.27	Out of bed (17th day)
28											45.91	Discharged to Sanit. (20th day)
Total		24.6	101.53		14.04	121.02						
Avg.		2.05	8.63		1.17	12.1						

TABLE VIII

A. S., MALE, 28—DUODENAL ULCER

Date	Daily N. Intake Gm.	Total N. Intake Gm.	Nitrogen Output: Urinary N. Gm.	Gastric N. Gm.	Fecal N. Gm.	Total N. Output Gm.	N. Balance Gm.	Cum. N. Status Gm.	P. P. Gm. %	Hem.	Wt. Kg.	Remarks
May											41.37	Gastrectomy,
26												May 27; 500 cc. W.B.
27-28	2.8											Cyanosis
28-29	12.8	27.6	41.93	14.19	1.53	57.65	−30.05					Cyanosis
29-30	12											Cyanosis
30-31	12.5											Cyanosis
June												Cyanosis
31-1	10.5	41.0	37.44	23.29	1.53	62.26	−21.26	−51.31				unexplained
1-2	18											Cyanosis
												disappeared
2-3	10											Cyanosis
3-4	12	32.5	34.5		1.53	36.03	−30.53	−55.84				disappeared
4-5	8.5										37	
5-6												
6-7												
7-8												
10												Out of bed June 10
Total		10.11	113.42		4.59	155.94						
Avg.		11.2	14.91		:51	17.33						

TABLE IX

W. C., MALE, 30—DUODENAL ULCER

Date	Daily N. Intake Gm.	Total N. Intake Gm.	Nitrogen Output: Urinary N. Gm.	Gastric N. Gm.	Fecal N. Gm.	Total N. Output Gm.	N. Balance Gm.	Cum. N. Status Gm.	P. P. Gm. %	Hem.	Wt. Kg.	Remarks
March 12									6.17	45	57.27	Gastrectomy 500 cc. W.B.
12–13	10.8											
13–14	21.75	51.82	49.06	54.94	1.77	105.77	−53.95					Fever—104°
14–15	19.27											Pulm. atelectasis, L.L.L.
15–16	19.27			13.25								Febrile
16–17	20.75	59.29	59.57		1.77	74.59	−15.30	−49.25			52.41	Febrile
17–18	22.75								6.60	30		
18–19	18.75											
19–20	22.75	64.25	58.49		1.77	60.26	+ 3.99	−45.26	6.43	27	53.22	Fever still 101.8 . 98.8°
20–21	22.75											
25												Out of bed (13th day)
31												Discharged—(19th day)
Total		175.36	167.11		5.31	240.62						
Avg.		19.37	18.57		.59	26.74						

TABLE X

J. B., MALE, 49—DUODENAL ULCER

Date	Daily N. Intake Gm.	Total N. Intake Gm.	Nitrogen Output: Urinary N. Gm.	Gastric N. Gm.	Fecal N. Gm.	Total N. Output Gm.	N. Balance Gm.	Cum. N. Status Gm.	P. P. Gm. %	Hem.	Wt. Kg.	Remarks
Mar. 1									5.85	40	42.72	Gastrectomy
1– 2	12	20.05	22.29	1.35	.66	24.3	− 2.01					
2– 3	8.05											
3– 4	8.54	19.18	29.32	.96	.66	30.94	−10.76	−12.77				
4– 5	10.64								5.99	33		
5– 6	6.55			.48							41.81	
6– 7	7.74	19.97	25.29		.99	26.76	− 6.31	−19.08				Fever—102.6°
7– 8	5.68										41.59	Fever
8– 9	5.47											Fever
9–10	6.63	19.73	32.88		.99	33.81	−14.08	−33.16				Fever
10–11	7.63										41.02	Fever
Avg.									5.21	36		Wound abscess—13th day —fever for 6 days after. Bed sores
April 8												Out of bed (37th day)
Total		79.13	109.28		3.3	116						Discharged (42nd day)
Avg.		7.91	10.98		.33	11.6						

TABLE XI

G. H., MALE, 39—CARCINOMA PYLORUS

Date	Daily N. Intake Gm.	Total N. Intake Gm.	Nitrogen Output: Urinary N. Gm.	Gastric N. Gm.	Fecal N. Gm.	Total N. Output Gm.	N. Balance Gm.	Cum. N. Status Gm.	P. P. Gm. %	Hem.	Wt. Kg.	Remarks
Feb. 1									6.36	60	64.8	Gastrectomy
2– 3	26.65	....	19.73	.71	1.69	22.13	+4.52	+ 4.52				
3– 4	27.9	....	16.36	1.26	1.69	19.32	+8.59	+13.11				
4– 5	25.1	....	13.31	1.82	1.69	17.32	+7.78	+20.89				
5– 6	22.08	....	18.76	.97	1.69	21.41	+ .67	+21.56	6.5	54	65.1	Fever 108°, L.U. atelectasis with pneumonitis (Xray confirmed)
6– 7	27.9	....	15.10	1.31	1.69	18.1	+9.8	+31.36				
7– 8	23.4	....	18.65	.46	1.69	20.8	+2.6	+33.96	6.36	50		
8– 9	23.4	....	14.94	.07	1.69	16.69	+6.71	+40.67				Temp. normal
9–10	23.4	....	23.87	....	1.69	25.56	−2.16	+38.51				
10–11	23.4	....	17.49	....	1.69	19.18	+4.22	+42.73			66.54	
11–12	23.4	....	22.96	....	1.69	24.65	−1.25	+41.48				
12–13	23.4	....	16.53	....	1.69	18.22	+5.18	+46.66				
13–14	23.4	....	21.30	....	1.69	22.99	+ .41	+47.07			67	Out of bed (13th day)
15									6.36	49		
16												Discharged (15th day)
Total	293.43	....	219.00	21.9	20.28	231.26						
Avg.	24.45	....	18.25	8.22	1.69	20.53						

TABLE XII

P. R., MALE, 48—DUODENAL ULCER

Date	Daily N. Intake Gm.	Total N. Intake Gm.	Nitrogen Output: Urinary N. Gm.	Gastric N. Gm.	Fecal N. Gm.	Total N. Output Gm.	N. Balance Gm.	Cum. N. Status Gm.	P. P. Gm. %	Hem.	Wt. Kg.	Remarks
Feb. 26									5.7	33	75	Gastrectomy
27–28	42.8	74.8	25.11	5.14	2.34	32.59	+10.21	+10.21				
28–31	32											
March												
1–2	32	64	35.94	17.12	3.51	56.57	+ 1.43	+17.64	6.46	33		
2–3	32											
3–4	32											
4–5	32	96	46.85	22.76	3.51	73.12	+22.88	+40.2				
5–6	32											
6–7	32										77.27	
8	32											Out of bed (8th day)
9	32										79.54	
10	32											
Total	362.8		107.9		9.36	162.28						Discharged (11th day)
Avg.	32.97		15.41		1.34	23.18						

TABLE XIII

A. V., MALE, 55—DUODENAL ULCER

Date	Daily N. Intake Gm.	Total N. Intake Gm.	Nitrogen Output: Urinary N. Gm.	Gastric N. Gm.	Fecal N. Gm.	Total N. Output Gm.	N. Balance Gm.	Cum. N. Status Gm.	P. P. Gm. %	Hem.	Wt. Kg.	Remarks
July 18									6.26	41	67	Erg. T.—270" Gastrectomy
19–20	14											
20–21	21	35	38.2	1.63	1	40.88	− 5.88	− 5.88	6.19	36		
21–22	30			11.91								Uxexplained fever—106°
22–23	6	66	42.64		1.5	55.55	+10.45	+ 4.57				Unexplained fever—104° Erg. T.—189"
23–24	30								5.87	39	68.7	Temp. normal
24–25	27											
25–26	30	87	32.23		1:5	33.73	+53:27	+57:84	6:07	35		Erg. T.—327"
26–27	30											
27–28	30											
28–29	35	100	24.67		1.5	25.87	+45:13	+102:97				
30	35								6:66	33	71.85	Out of bed (9th day) Erg. T.—348"
Aug. 1												Discharged (11th day)
Total		288	137:94		5.5	156.03						
Avg.		26.2	12.54		:5	14.18						

TABLE XIV

C. N., MALE, 59—CARCINOMA PYLORUS

Date	Daily N. Intake Gm.	Total N. Intake Gm.	Nitrogen Output: Urinary N. Gm.	Gastric N. Gm.	Fecal N. Gm.	Total N. Output Gm.	N. Balance Gm.	Cum. N. Status Gm.	P. P. Gm. %	Hem.	Wt. Kg.	Remarks
July 10									6.25	38	54	Erg. T.—213" Gastrectomy
11–12	18											
12–13	18	60	37.36	4.52	1:56	43:46	+16.54	+16.54	5.75	37		
13–14	24											Fever—104°.Pulmonary path.?
14–15	24			5.04								Fever—101.6°
15–16	31	85	29.1		1:56	35.7	+49.3	+65.84				Temp. normal
16–17	30								5.43		56	Erg. T.—144"
17–18	30											
18–19	30	90	71.21		1.56	72.77	+17.23	+83.07				Erg. T.—231"
19–20	30								5.34			Out of bed (10th day)
20–21	30											
21–22	30	90	38.91		1:56	35.97	+54.03	+137.10				Erg. T.—327"
22–23	30								5.71	38	59.3	Discharged (13th day)
Total		325	176.5b		18.92	187.9						
Avg.		27.08	14.72		.52	15.66						

TABLE XV

E. B., MALE, 35—DUODENAL ULCER

Date	Daily N. Intake Gm.	Total N. Intake Gm.	Nitrogen Output: Urinary N. Gm.	Gastric N. Gm.	Fecal N. Gm.	Total N. Output Gm.	N. Balance Gm.	Cum. N. Status Gm.	P. P. Gm. %	Hem.	Wt. Kg.	Remarks
Dec. 1									5.24	32	36.82	Gastrectomy. 3 units plasma
1–2	8.4											
2–3	36	68.4	19.07	22.529	7.08	38.68	+29.72	+19.72				
3–4	24											Fever—103°. Purulent bronchitis?
4–5	24											Fever—101.8°
5–6	24	72.00	22.07	10.145	7.08	39.3	+32.7	+62.42	5.31	33		Temp. normal
6–7	24											
7–8	24			18.3								
8–9	24	72	21.23		7.08	46.61	+25.39	+87.81	4.77			
9–10	24											
10–11	24	48	18.88		4.72	23.60	+24.94	+112.75				Out of bed (10th day)
11–12	24											
18									5.41	39	42.67	Discharged (17th day)
Total		260.4	71.25		25.96	148.19						
Avg.		23.68	6.48		2.36	13.47						

TABLE XVI

R. B., MALE, 48—DUODENAL ULCER

Date	Daily N. Intake Gm.	Total N. Intake Gm.	Nitrogen Output: Urinary N. Gm.	Gastric N. Gm.	Fecal N. Gm.	Total N. Output Gm.	N. Balance Gm.	Cum. N. Status Gm.	P. P. Gm. %	Hem.	Wt. Kg.	Remarks
Nov. 20									6.14	43	60.23	Erg. T.—54″
22–23	38.8	80.8	34.18	3.97	1.14	40.29	+40.51	+40.51				Nov. 22—Gastrectomy—500 cc. W.B.
23–24	42											
24–25	36											
25–26	36	108	67.18	5.84	3.21	76.23	+31.77	+72.28				
26–27	36											
27–28	36									63		Erg. T.—110″
28–29	36	108	55.64		3.21	58.85	+48.15	+120.43				
29–30	36								6.3	44		Erg. T.—120″
Dec. 30–1	36	72	44.25		1.14	46.39	+24.61	+145.04				
1–2	36											
3											64.55	Erg. T.—160″
8												Out of bed (10 days) Discharged (15th day)
Total		368.8	201.25		8.7	218.7						
Avg.		36.88	20.13		:87	21.87						

TABLE XVII

MASTER TABLE SHOWING NITROGEN BALANCE STUDIES IN 16 CASES OF GASTRECTOMY

Group	Name	Sex	Age	Orig. Body Weight Kg.	Diagnosis	No. Days Under N. Study	Average Daily N. Intake Gm.	Daily N. Intake per Wt. Kg.	Average Daily Fecal Nitrogen	Loss or Gain of Nitrogen Gm.	Loss or Gain of Body Wt. Kg.	Days of Return Strength	Days in Bed	Remarks
A	G. W.	M	58	54.81	Ca.-pyl.	13	4.23	:08	:48	− 58.68	−5.26		17	Uneventful
	A. D.	M	59	62.5	D. U.	10	4.31	:07	:22	−113.7	−4.78		19	Pulmonary atelectasis with low-grade fever to 11th day
	T. S.	M	64	55.5	D. U.	8	2.1	:04	.5	− 96.01	−7.3		18	Temp. rise from 2nd day to 10th. Mild cold. No other complications
	P. B.	M	34	64.32	G. U.	8	2.78	:04	:5	− 78.71	−4.27		23	Fever 102.4° F. from 9th to 12th days. Wound infection (abscess) on 21st day
	D. F.	M	55	59	Ca.-pyl.	10	2.42	:04	:5	− 67.86	−9	Not on 12th day	18	Pyrexia—102° F. from 5th to 8th days, p.o. wound infection discovered 7th day; wound separation 26th day
	M. K.	M	55	68	D. U.	9	7.4	:11	:53	−148.84	−6.19	Not on 12th day	13	Hematemesis (500 cc.) on 2nd p.o. day Temp. 104° F. on 4th day to normal in three days
	F. Mc.	M	46	52.5	D. U.	12	2.05	.04	1.17	− 96.66	−6.59	Not on 12th day	17	Unexplained pyrexia (103° F.) on first to sixth days
	N. G.	M		70.5	Ca.-pyl.			:06			−7.8		24	P.O. pneumonia on 8th day; fever to 12th day. Wound separation 12th day
	Average												18.6	
A′	A. S.	M	28	41.37	D. U.	9	11.2	:27	:51	− 55.84	−4.37		14	Unexplained cyanosis from 1st to 6th p.o. days
	W. C.	M	30	57.27	D. U.	9	19.37	.18	:59	−45.26	−4.05		13	Fever from 2nd to 6th p.o. day (104° F.) Pulmonary atelectasis
	J. B.	M	49	42.72	D. U.	10	7.91	:19	:33	− 33.16	−1.7		37	Fever 102.6° F. from 8th day. Low wound infection and peritoneal abscess found on reoperation, 13th day. Bedsores
B	G. H.	M	39	64.8	Ca.-pyl	12	24.45	.42	1.69	+ 47.07	+2.2		13	P.O. atelectasis. (X-ray confirmed) 3rd p.o. day, temp. 103° F., falling to normal in three days
	P. R.	M	48	75	D. U.	7	32.97	:44	1.34	+ 68.05	+4.54		8	Uneventful
	A. V.	M	55	67	G. U.	11	26.2	:48	.5	+102.97	+4.85	Between 5th and 9th days	9	Temperature 106° F. on 3rd day—again 104° F on 4th day. Normal thereafter
	N C.	M	59	54	Ca.-pyl	12	27.08	:6	:52	+137.10	+5.3	Between 4th and 8th days	10	Fever 104° F. on 3rd p.o. day—probable pulmonary "pathology." Fever lasting two days
	E. B.	F	35	36.82	D. U.	11	23.68	:61	2.36	+112.75	+5.85		10	Fever 103° F. on 4th p.o. day—purulent bronchitis. Temp. normal on 5th day
	R. B.	M	48	60.23	D. U.	10	36.88	:6	:87	+145.04	+4.32	Between 4th and 6th days	10	Uneventful
	A. H.	F	33	60	Ca.-pyl		30	.5			+4		10	Uneventful
	G. S.	F	75	55	Ca.-pyl		24	.44			+6		8	Uneventful
Average													9.8	

Table XVII is a master table summarizing the findings in the three groups with relevant correlative calculations and with columns numbered for ready reference. In A, there was included an additional case (R. G.), in whom the nitrogen-balance study was not done, but in whom the weight-curve and the period of stay in bed were recorded. In B, there were also two such cases (A. H. and G. S.).

The Nitrogen Intake.—Column 8, Table XVII, shows that in both A and A′ the nitrogen intake was abnormally low, ranging from a minimum of 2.1 Gm. per day (T. S.) to a high of 7.4 Gm. (M. K.), most values being in the neighborhood of 2 or 4 Gm. daily. The intake per kilogram body-weight ranged from 0.04 (T. S., P. G., D. F., and F. Mc.) to 0.11 Gm. (M. K.). In B, the intakes ranged from 24 (G. S.) to 37 Gm. daily (R. B.), or from 0.39 (A. V.) to .65 Gm. (E. B.) per Kg. body-weight. These intakes are much higher than those obtained by high protein diets, and in a 70-Kg. man would correspond to from about 750 to 1350 Gm. of meat daily.

Urinary Nitrogen.—In A and A′, except for the cases in which melena occurred, the urinary nitrogen excretion was unusually low, ranging from 7 to 12 Gm. as a daily average, except for G. W. (Table I), whose excretion rose to 15.5 Gm. on the seventh day, without assignable cause, and for A. D. (Table II), whose excretion was 31.88 Gm. for the first two days. There is, thus, in this and in our previous series, little evidence of a significant and sustained large loss of urinary nitrogen following such a major surgical insult as gastric resection. It must, however, be remembered that all these patients had undernutrition before they came to operation and were in practical starvation for several days following. The finding by Cuthbertson[6] that starved animals sustaining injuries do not lose the amount of nitrogen lost by previously normal animals, may explain this small loss encountered in our cases.

In the group with hemorrhage, or suspected hemorrhage, where the gastric nitrogen was unusually high, there was also a high urinary nitrogen excretion—14.9 Gm. for A. S. (Table VIII), 18.17 for M. K. (Table VI), and 18.57 for W. C. (Table IX). Here the high urinary nitrogen may be explained on the basis of "alimentary azotemia," which has been reported by Chunn and Harkins,[17] and others, as accompanying gastro-intestinal hemorrhage.

In B, as may be expected from the high nitrogenous diet, the urinary output was generally considerably larger. E. B. (Table XV) was an exception, with an average excretion of only 6.48 Gm. daily. However, she had suffered a large loss of weight before entry into the hospital, at which time her weight was only about 37 Kg. The other cases had average urinary nitrogen values of from 12.54 (A. V., Table XIII) to 20.13 Gm. (R. B., Table XVI). These values do not differ much from the values of our first series of feeding cases.

The Fecal Nitrogen.—In the total number of ten cases, in the Groups A and A′, except for the three cases of postoperative hemorrhage, the fecal

excretion was inclined to be on the starvation level—mostly under 0.5 Gm. daily. In only one case (F. Mc., Table VII), did it consistently average over 1 Gm. daily. In the three cases of actual or suspected hemorrhage, the fecal excretion was over 0.5 Gm., but under 1 Gm. In B, the excretion values were over 0.5 Gm. daily in two cases, over 1 Gm. in three cases, rising to over 2 Gm. daily in one case. This is to be expected with the high nitrogen intake, although it falls below the average value of 10 per cent of the intake, as is assumed to be the case with the ingestion of natural food. This finding may indicate that preparations like amigen are more completely absorbed than natural food. These fecal nitrogen values accord with the findings in our previous series. Column 10, Table XVII, gives the average daily values for fecal nitrogen.

Gastric Nitrogen.—The amount of nitrogen present in the Wangensteen suction varied from a fraction of 1 Gm. daily to almost 10 Gm. It is possible that figures above this may point to a postoperative hemorrhage. In the one case in which there was frank postoperative hemorrhage (M. K., Table VI) and in two in whom postoperative hemorrhage was suspected, this figure rose to as high as 23 Gm. a day (M. K., Table VI).

The Total Nitrogen Output.—Although the urinary values were low in A and A′, the additional nitrogen loss in the gastric suction tended to make up the total nitrogen values, so that the total nitrogen excretion was not far below accepted normal values—the lowest daily average being over 9 Gm. (G. W., Table I, and D. F., Table V). However, only in the cases with detected or suspected hemorrhage was total nitrogen excretion much above normal accepted values (M. K., Table VI, A. S., Table VIII, and W. C., Table IX).

In B, total nitrogen excretion was high as might be expected from the increased nitrogen intake.

The Nitrogen Balance.—With the exception of one three-day period in the case of W. C. (Table IX), the nitrogen balance in A and A′ was consistently negative in the two groups. In B, with the exception of the first day, when the intake in some cases was deliberately restricted, the nitrogen balance was consistently positive throughout the feeding period. This nitrogen gain on the part of the body ran from a fraction of 1 Gm. a day to as much as 55 Gm. in a three-day period.

The Cumulative Nitrogen Status and the Weight-Curve.—Columns 11 and 12 in Table I represent, respectively, the cumulative nitrogen status and the weights of the patients. The cases in A and A′ all showed nitrogen deficits ranging from 35.55 (W. C. Table IX), to 140.60 Gm. (T. S., Table III). These were associated with marked weight losses ranging from 1.7 Kg. (J. B., Table X), to 10.23 Kg. (A. D., Table II). In the cases in B, the nitrogen surplus ranged from 45.13 Gm. (A. V.) to 145.04 Gm. (R. B.), and the weight gains from 2.2 Kg. (G. H.) to 6 Kg. (G. S.). Theoretically, for every 32 Gm. of nitrogen lost or gained by the body, there ought to be

a corresponding loss or gain of 1 Kg. of weight. Unfortunately, for a better correlation, the weights were not taken simultaneously with the termination of the nitrogen balance studies. However, it can be seen from the figures in all three groups that, although there was no strict mathematical parallelism between the magnitude of nitrogen deficits and surpluses, large losses of nitrogen were associated with large losses in weight and large gains of nitrogen with large gains in weight.

The Plasma Protein and Hematocrit Levels.—In the previous report it was stated that the general tendency of the plasma protein level was downward in the control group, and upward, or relatively stationary, in the following group. In the present group of six control cases, a downward tendency was discerned. In A′ there seemed to be a suggestive rise. The picture was somewhat erratic in B, the trend being upward in three, stationary in one, and downward in two. Nor did there seem to be any consistent pattern to the hematocrit values except in the two cases with postoperative hemorrhage. In any event, the changes in the protein values downward or upward did not seem significant, and in the absence of blood volume determinations neither value is interpretable.

Ergograph Time and Postoperative Asthenia.—Patients D. F. (Table V), F. Mc. (Table VII), and M. K. (Table VI) in A and patients R. B., C. N., and A. V. in B were tested with the bedside ergograph. The tests were performed one or two days before the operation and in the fourth, eighth day and twelfth day postoperatively. As may be seen from column 13 of Table XVII, both groups showed a depression of the ergograph time on the fourth postoperative day. In the cases in A the return to normal had not occurred on the twelfth postoperative day, while the three cases in B had exceeded their initial ergograph time in from the fifth to the ninth day postoperatively. Graphs 1 and 2, respectively, represent a control case (D. F., Table V), and a feeding case (C. N., Table XIV). The initial ergogram-time (E. T.) in Panel I (Graph 1) was 120 seconds. The E. T. in Panels II, III and V, respectively, 4, 8, and 11 days postoperatively are 69, 78, and 108 seconds. Thus, on the eleventh day, the endurance had not yet returned to the initial level. The initial E. T. Panel I, Graph 2, two days preoperatively, was 213 seconds. The E. T. in Panels II, III, and IV, respectively, four days, six days, and eight days postoperative were 164, 231 and 327 seconds. Thus, while there was also a depression on the fourth postoperative day, on the sixth postoperative day the endurance had already surpassed the initial endurance. This seemed to correspond with the subjective feeling of asthenia, or lack of it, in these two groups.

The Length of Stay in Bed.—As far as the authors are aware, the subject of when an operative patient should be allowed to get out of bed has never been examined critically and objectively. Offhand, two factors seem to enter into this consideration: The healing of the operative wound and postoperative asthenia. In the control cases, there would be a number expected to have

such malnutrition that the wound would not heal or would heal slowly. One case in our previous series and one in the present series showed this condition, culminating in wound dehiscence (J. B.). Thus, these two factors seem to play a rôle in the prolonged bed-stay of this group, sometimes one factor, sometimes the other, in the dominant rôle.

In the patients in the feeding group, in whom nutrition was supported by this type of rich feeding, the speed of wound healing would be expected to follow, at least, the norm demonstrated by the work of Howes, Sooy and Harvey,[7] and the maximal tensile strength of the healed wound would be in the neighborhood of 10 to 12 days. On the other hand, the ergograph-time had topped the initial reading in from the sixth to the eighth day. Thus, it appears that in the feeding group it is the speed of wound healing, rather than the postoperative asthenia, which retards the patients' stay in bed. It will be seen from column 14 of Table XVII that the average number of days in bed is 19.25 days for A. Strictly considered, this average figure is too low, since M. K. (Table VI), the one patient with a stay in bed of 13 days, was fed for a period of ten days preoperatively, resulting in a gain of 3.3 Kg. This improvement of his preoperative nutritional state makes it necessary, in interest of strict comparison, to exclude him from the series. With this done, the average period of stay in bed would be 20.1 days. In the feeding group, on the contrary, the corresponding average of 9.5 days (column 14, Table XVII) in bed is higher than it should, theoretically, be. To allow patients convalescing from an operation of the magnitude of gastrectomy out of bed in eight days is a radical departure from surgical tradition, and usually involves a compromise in which two or three additional days are added to the period of recumbency. It may also be mentioned that the patients in B clamored to get up by about the seventh day, while those in A had to be encouraged to get up.

Complications.—(Column 15, Table XVII).—The small series of 11 patients in A and A′, and of eight in B, are too small to make any statistically significant analysis of the complications as affected by postoperative feeding or nonfeeding. There were three pulmonary complications in each group, but the recovery seemed to be considerably longer in A than in B. There were three wound infections in A and A′, one wound separation, and one case of bedsores, while the cases in B were free from these complications. The case of bedsores is interesting in view of a recent work by some of the present authors[8] on the relationship between bedsores and protein nutrition. At the time the bedsores occurred, the plasma proteins of J. B., (Table X) was 5.01 Gm. per cent. Only two of the patients in A and A′ may be said to have had an uneventful course in any way, while there were four uneventful cases in B.

In A, another complication was encountered, *i.e.*, a delayed type of disturbance of gastro-intestinal function occurring at about the sixth to ninth postoperative day in five of the eight cases. It manifested itself in the form

of abdominal distention with vomiting and inability to take more than a small amount of liquid food at frequent intervals. Two factors may be evoked to explain this phenomenon: (1) Edema about the stoma; and (2) deficient peristalsis, tone and absorptive faculty of the small intestine consequent to undernutrition. This did not occur in any of the cases in B.

Disadvantages.—In the previous report, the principal disadvantage of this feeding regimen was said to be the taste of the feeding mixture. This still remains the main drawback. However, in the rather extended experience we have had with the use of the mixture, it seems that most patients readily yield to persuasion and will continue taking it if they realize that it produces beneficial results. When the choice is left to the patient, whether to take feedings by mouth or by tube, the oral method is usually preferred.

Discussion and Comments.—Altogether, 24 patients convalescing from gastrectomy have been subjected to nitrogen balance studies in this and in the previous series. Three additional patients had only their weights and their length of stay in bed recorded. There was, thus, a total of 13 in the control group and 14 in the feeding group. In none of the patients in the control group, except in the cases with actual or suspected gastric hemorrhage, did there seem to be a loss of urinary nitrogen above that accepted as normal average. Cuthbertson[6] has shown a nitrogen loss to occur following trauma. Albright,[9] and Browne[10] have ingeniously integrated this with Selye's[11] "alarm reaction" and an hypersecretion of hormone "s" from the adrenal cortex preventing tissue anabolism. These workers have called this period of nitrogen loss the antianabolic period. If this phenomenon had occurred in our series, it certainly was not marked. However, as pointed out before, the previous state of undernutrition might have modified or altogether eliminated the antianabolic period.

In the feeding group, the early ability of the patients to achieve nitrogen balance as well as the consistent upward weight curve may be interpreted to mean that if an antianabolic period was present, it was correctable by high amino-acid feeding. This, again, is not in apparent conformity with Cuthbertson's and Browne's findings, but, again, the state of undernutrition of our patients may reconcile the divergence of these results.

It is also apparent that although the urinary excretion of nitrogen may be small in these cases, the addition of the nitrogen lost in the gastric suction may raise the total nitrogen output considerably above the amount prescribed as optimum protein requirements for the average person, namely, 90 Gm. of protein or 14.4 Gm. of nitrogen daily.

The level of nitrogen feeding attained in the patients in B, as has been pointed out elsewhere in this report, is much higher than that of a high protein diet. It is, roughly, two to three times the average amount of the total nitrogen loss. There may be said to be at least two justifications for giving such large doses of nitrogen. In the first place, it is not known just what specific amino-acids are required to replace the nitrogen loss, and this

increased alimentation may be considered an attempt to offer enough of an assortment of amino-acids in sufficient quantities so that the body can select what it needs under optimum conditions and reject the rest. Approximately 50 per cent of the bulk of amigen is composed of the ten essential amino-acids, 40 per cent being unessential amino-acids and the balance, moisture and ash. It is altogether unlikely that the proportions of the ten are ideal, and, it is highly probable that the unessential moiety is excessive. Therefore, an ideally economical utilization cannot be expected from such a mixture. The wonder is that it should be so well utilized that the total nitrogen excretion in B were not larger than they are. However, it is quite possible that a drastic reduction of the unessential moiety would make for a greater economy of utilization.

The second justification for the use of these large amounts of nitrogen is that all of these cases, except one, M. K. (Table VI), were in a state of undernutrition when they came to operation. This increased alimentation is, therefore, necessary not only adequately to make up the nitrogen loss during and after the operation, but also to replace the body tissues lost as a result of the preexisting undernutrition. The fact that some of these patients retained as much as 53 Gm. of nitrogen in three days shows the need of the body to rebuild itself.

In this connection, Elman's[12] summary, concluding a report on the oral use of amigen in surgical patients, may be worth while quoting. He stated: "The amino-acids of hydrolyzed casein (amigen) have been administered directly into the gastro-intestinal tract in several types of surgical patients in order to spare the need for protein digestion. Absorption and utilization occurs under circumstances when whole protein is ineffective. The use of amigen also seems to permit the assimilation of much larger daily amounts of protein nourishment than seems possible when whole protein is given."

The tendency of the plasma protein level not to rise even after there is a considerable gain in body weight and a positive nitrogen balance for several days needs further study. Similar results have been obtained with post-operative patients by other workers (Ariel, *et al.*,[13] Casten, Bodenheimer and Barcham,[14] and Meyer[15]), although in the case of the observations of these workers, no high amino-acid feedings had been given and the weight curve was not followed.

These experiments recall to mind a practice reported by Soviet surgeons of introducing milk, egg and sugar mixture into the intestines during celiotomy with marked, prompt benefit to the patients and a reduced mortality rate. There were, thus, two separate beneficial effects reported as resulting from the use of such feedings—one immediate and the other delayed. The feeding consisted of 400 cc. milk, 20 cc. sweet butter, 50 grams sugar, 2 eggs, and 50–70 cc. distilled alcohol. Analysis shows that it would not yield more than 1500 calories, even if the alcohol was 95 per cent. There was a nitrogen content of about 8 Gm. The immediate beneficial effect is probably attributable

to the alcohol, since it is difficult to understand how the caloric and nitrogen intake could accomplish this. And since the caloric and nitrogen intakes are subbasal for even one day, it is also difficult to explain the delayed beneficial effects, unless two or three such feedings are given daily throughout convalescence.

SUMMARY AND CONCLUSIONS

In a further and larger series of patients undergoing gastrectomy for either peptic ulcer or carcinoma of the stomach, it was found that:

(1) In the series under the classical ward regimen there was a consistent nitrogen deficit and loss of weight, and a prolonged stay in bed, confirming the preliminary results of our previous series. Objective ergography also showed postoperative asthenia, which had not disappeared even on the twelfth postoperative day.

(2) In the series fed with high caloric and high amino-acid mixtures, there was a consistent nitrogen surplus, a steady gain in weight and a stay in bed of less than one-half the control series. The ergograph showed an early return of endurance in from the fifth to the sixth postoperative day to above that of the initial reading.

(3) The principal source of nitrogen loss in postgastrectomy convalescence was the starvation postoperative regimen.

(4) Whether there was actually a larger excretion of urinary nitrogen in the patients in the control group over their preoperative level has not been determined.

(5) The nitrogen loss resulting from the gastric suction was considerable.

(6) The nitrogen loss, however, was correctable by feeding an easily assimilable high amino-acid mixture.

(7) Contrary to the impression gathered in the previous series, that there was a tendency of the plasma protein level to fall in the control cases and to rise during the feeding cases, in the present series there was no consistent tendency during the seven to twelve days during which the patients were under study.

(8) An hyperalimentation regimen, consisting of high caloric and high amino-acid feeding postoperatively, has been worked out, found practical, and is recommended in the routine case of gastrectomy in order to circumvent nitrogen loss, shorten convalescence, and prevent postoperative asthenia.

(9) While the complications in the feeding group are fewer and less severe than those in the control group, the present series is too small to lead to any statistically significant conclusions.

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BRIEF COMMUNICATION

THE CONSTRUCTION AND USE OF A BEDSIDE ERGOGRAPH*

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In the course of some studies on convalescence, it became desirable, objectively, to determine the strength and endurance curve of patients recovering from surgical operations. Since ergographs then available were all devised for the ambulatory patient, it became necessary to construct the present bedside model.

Construction.—The bedside ergograph as shown in Figure 1, consists of three essential parts:

1. *The framework* consists of arboard A, 10″ x 56″, supported at the proximal end by the bed and the distal end by a support SP reaching to the floor. The Thomas splint S is fixed to this armboard. In this way, a stable cradle is made within which the entire upper extremity below the shoulder rests while the test is being conducted. The splint also serves to immobilize the shoulder.

2. *The weight-lifting system,* consisting of 3- and 5-Kg. weights suspended on a cable, which rides over pulleys P_1 and P_2, at the digital end of the apparatus, then running horizontally over the armboard to join the handle H, which is grasped in the hand of the subject.

3. *The recording system* consists of a stylus ST attached by a string STr through bar B to the weight attachment. As the weight is lifted or lowered, the stylus is lowered or lifted. This is recorded on a moving drum D. The rate of pulling is paced by a metronome set at 2- or 3-second intervals, but constant for each subject.

Technic for Performing Tests.—The apparatus is fitted to the recumbent subject in such a way that the arm of the patient is slipped into the splint and the shoulder rests on the proximal part of the armboard. The long axis of the apparatus makes an angle of about 30° with the long axis of the bed. The arm and forearm are placed in the anatomic position, *i.e.*, in full radial

* This work was done under a contract recommended by the Committee on Medical Research between the Office of Scientific Research and Development and New York University. Read in abstract form before the Committee on Convalescence and Rehabilitation of the Committee on Medical Research, November 15, 1943.

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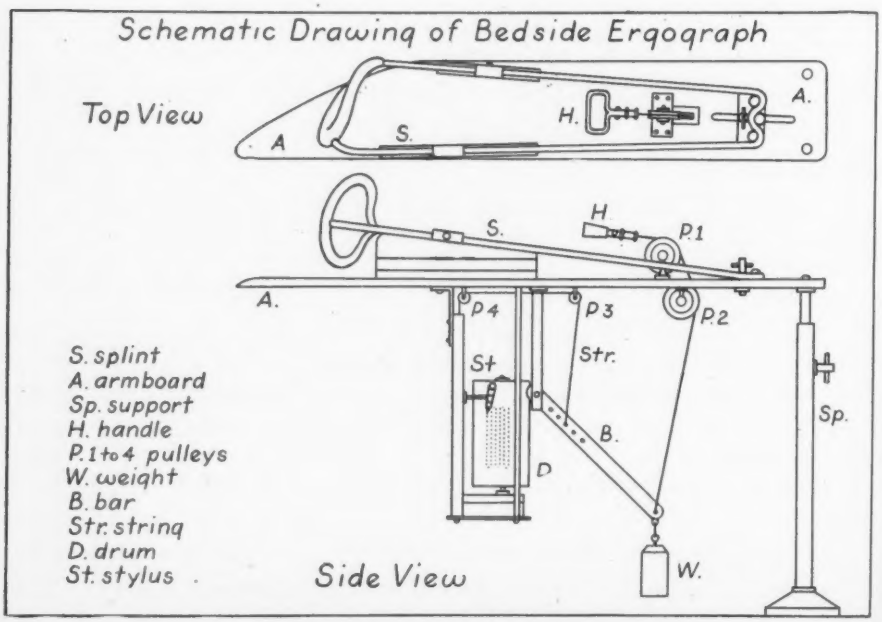


FIG. 1.—A line drawing of the apparatus.

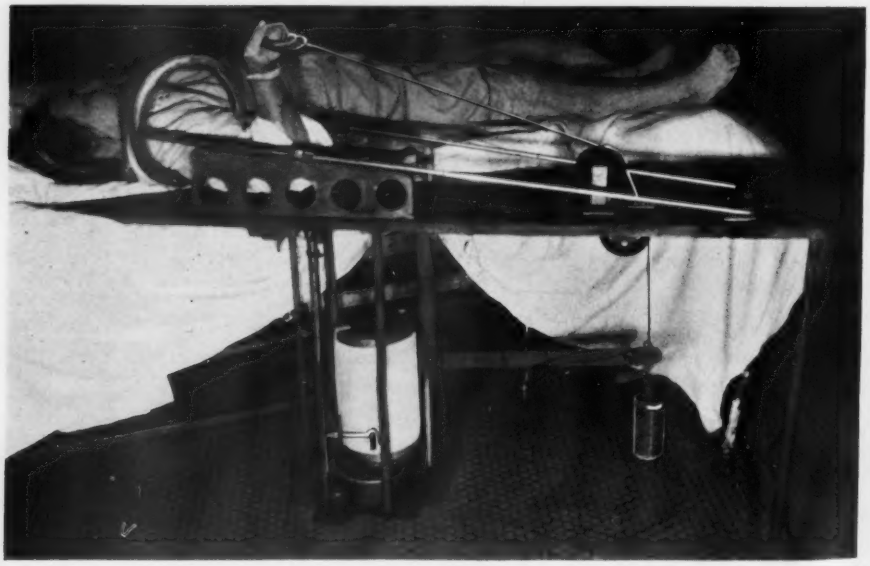
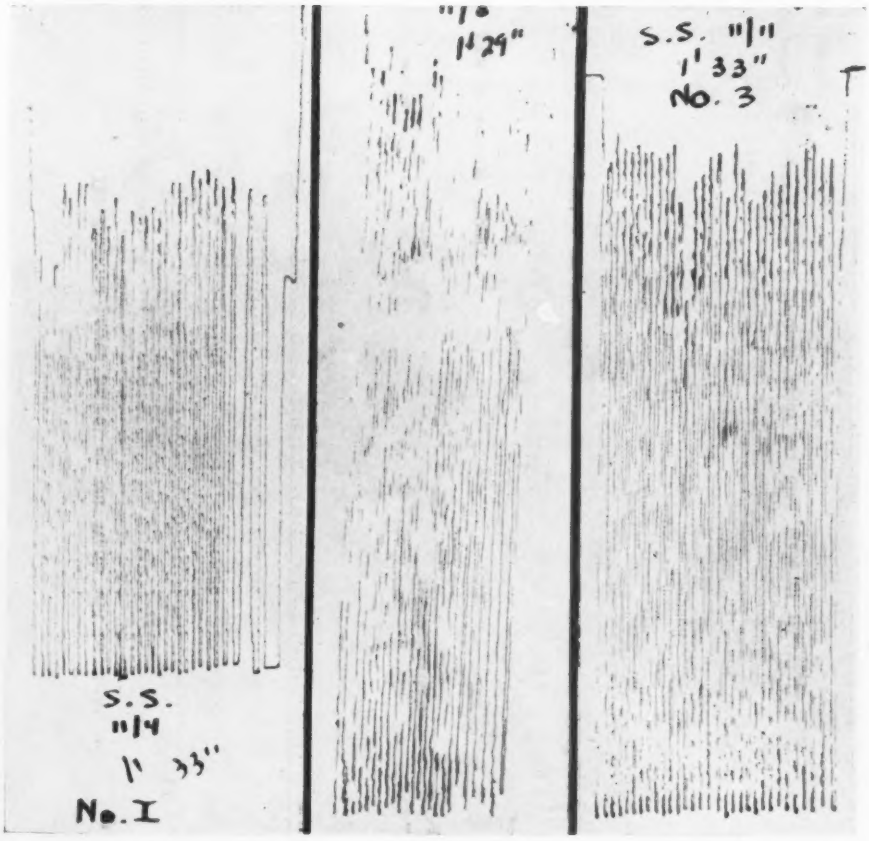
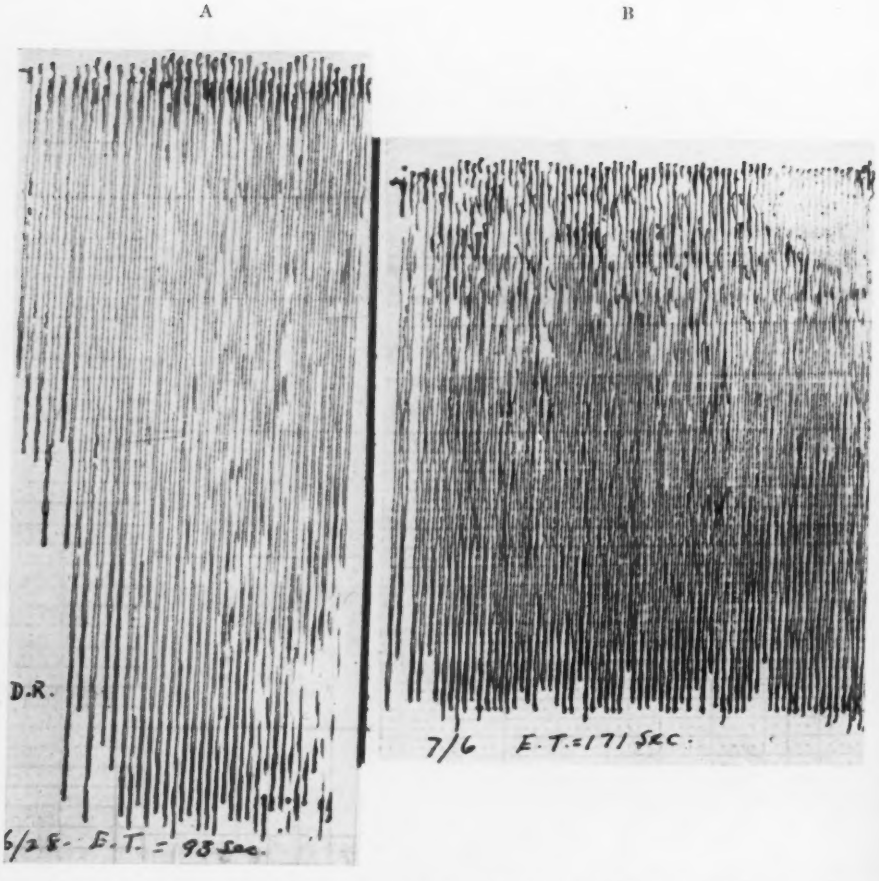


FIG. 2.—Patient with ergograph fitted.

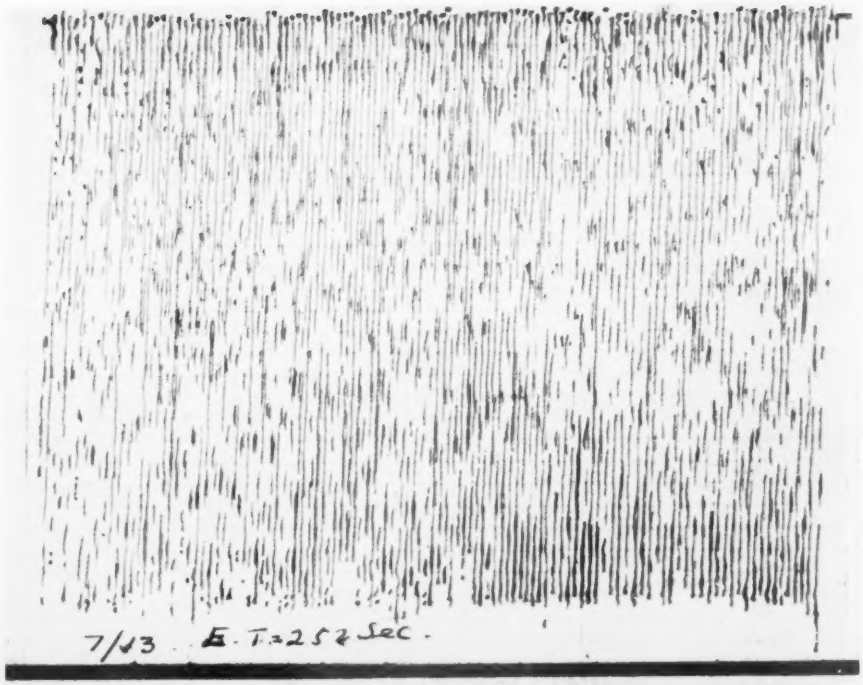


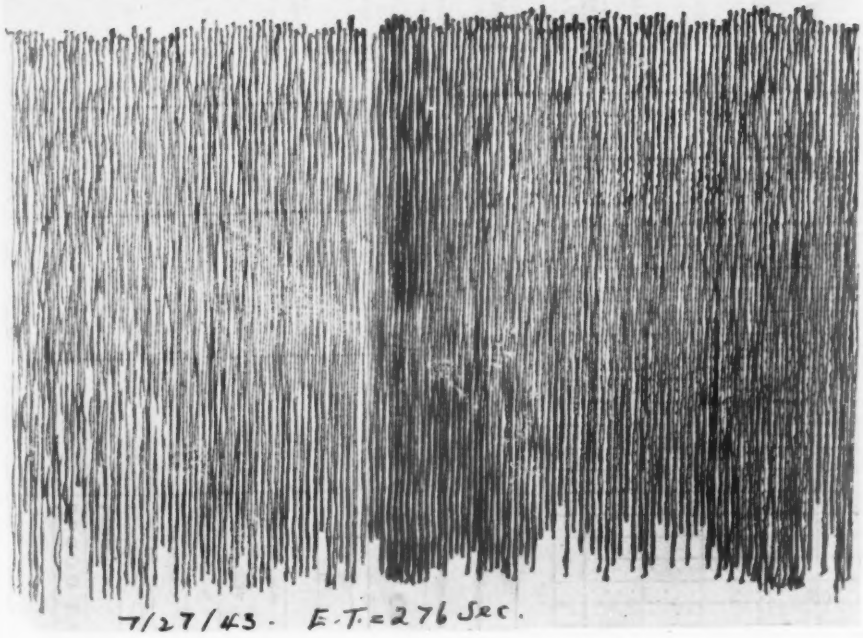
GRAPH. 1.—Three ergograms of a normal subject taken three and four days apart, showing no significant change in the endurance in the three tests. The ergograph times are, respectively, 93, 89 and 93 seconds.



GRAPH 2.—Four ergograms of a patient admitted with malnutrition following a poorly functioning gastrectomy. The initial E.T., Panel I, is 93 seconds; the E.T.'s of Panels II, III, and IV, taken a week apart, after the institution of high caloric and high amino-acid feeding and an improvement in nutrition, were, respectively, 171, 252, and 276 seconds. It is to be noted that the amplitude of the excursions is not important since it varies with the length of the lever arm (bar) to which string is attached.

C





D

deviation; the arm is now kept in a fixed position by a linen hammock suspended between the bars of the splint. The handle H is then grasped and the test is ready to start. Fig. 2 is the photograph of a patient with the ergograph fitted. The subject is instructed to pull on the weights up to 90° flexion each time the metronome ticks. The patient stops when he feels a painful fatigue in his biceps muscle. This end-point cannot, therefore, be called entirely objective. The endurance may be expressed either as the number of excursions recorded on the drum, or the length of time from the beginning of the first excursion to the end of the last. This latter, expressed in seconds, is called the ergograph time (E. T.). Graphs 1 and 2 are respectively the ergograms of a normal person and a patient convalescing from malnutrition.

SUMMARY

A bedside ergograph has been described to determine the endurance curve of patients postoperatively. While a gross study, it, nevertheless, seems to give significant and consistent results.

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